KNOW THE NETWORK, KNIT THE NETWORK:

APPLYING SNA TO N2C2 MATURITY MODEL EXPERIMENTS

Topic 5: Experimentation and Analysis

Topic 2 (alternative): Networks and Networking

Topic 8 (alternative): C2 Assessment Metrics and Tools

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1 INTRODUCTION

ELICIT aims to investigate social and cognitive impacts of command and control approaches and organisational structures within the context of information sharing, shared awareness and knowledge task. Nowadays, command and control is increasingly seen as the result of multidimensional factors and processes that intertwine the physical, information, cognitive and social domains, highlighting the decisive human element. Thus, the ELICIT experiments reflect (social) networking from which patterns of interaction (key command and control factor) may be drawn.

For years, social network analysis (SNA) has been a scientific methodology to assist in the explanation of networking and inter-relationships between actors. Rather than seeing individuals as discrete units of analysis, SNA focuses on how the structure of ties affects individuals and their relationships. Its long-time established metrics seem therefore suitable for application in the ELICIT Case Study. In fact, SNA is a main concept of the Office of Force Transformation to study dynamics and personal interactions occurring in the battlefield and to explain forces and influences that determine how decisions and choices are made, especially in critic periods (Edison, 2005).

Benefiting from SNA teachings and NetDraw software, we select a relevant analytical view, encompassing the network's structure and location properties (roles and positions), based upon the geodesic distance concept. From this concept, conclusions may be derived with respect to underlying patterns in the network, prefigured in terms of centrality, embeddedness, activity, clustering and also network reach (paths) and structural cohesion. Through SNA, we recognise the emergence of individuals that find their connection mutually beneficial, giving form to a social interaction based on trust, shared values and beliefs, and allowing the sharing of information. This social networking in ELICIT significantly affect the group's performance and effectiveness. Therefore, SNA may provide additional means to assess the social networks that seem most critical to success and even develop different forms to promote collaboration, identifying weak spots, bottlenecks and key connectors and helping to improve the network's ability to be aware and responsive to information so as to create a more efficient and effective organisation.

2 UNDERSTANDING HUMAN INTERACTION

Already for a long time sociologists have realized the importance of information flows and of patterns of interaction between individuals to the understanding of the human society's functioning.

In 1922, Professor John Almack published a paper – *The Influence of Intelligence On The Selection of Associates* – that foresaw a sociometric tool capable of identifying relationships within a group of preschool children. Twenty years later, Radcliffe-Brown invented the expression network of relations to describe the interaction patterns that construct social structures (Zack, 2000). Since then, and framed in the global concern towards more relational, contextual and systemic understandings, the notion of social networks has provided a new way of thinking about social structure.

Maintaining a dynamic essence and rejecting a reductionist perspective, social network expertise continues to develop increasingly complex concepts to apply to all sorts and levels of networks. In fact, social network analysis has proven itself as an extremely successful method to describe organisations, to measure the effects of organisations and to explain diversified social phenomena, from friendship patterns to disease spread. Eighty years after Almack's article, Cross, Parker and Borgatti state that SNA makes the invisible visible and the intangible tangible, praising it as the metaphor for understanding organisation forms or structures (Cross, Parker and Borgatti, 2002).

Focusing on the two core elements of network data (the nodes or actors and the edges or relations), we combined the relational view, in which the organisation is considered a product of the density and strength of its relationships (cohesion), and the positional approach, advocating the importance of role sets and status (in the 1968 book *Social Theory and Social Structure*, Robert K. Merton already called attention to role setting, that is, the set of relationships that emerge because one occupies a given role or status). In fact, if the first major emphasis of SNA is to see how actors are located or embedded in the overall network, then its second major emphasis is to understand how the whole pattern of individual choices gives rise to more holistic patterns.

Departing from positional and relational approaches, SNA undertakes a major interpreting work that builds upon diversified metrics and measurements to accomplish successfully a few management tasks, including the identification of issues that hinder organisations, requiring modification to specific behaviours and organisational design elements in order to improve organisational efficiency, competitiveness, effectiveness and success.

2.1 Sociograms – A Picture Worth a 1000 Words

Assessing the patterns of relationships in organisations does indeed reveal a number of interesting and actionable considerations, from identifying individuals that are highly central in networks (controlling information diffusion or decision-making processes) to understanding who is peripheral in the network so that an effort may be implemented to strengthen those individuals' ties so that resident expertise in the network may be effectively utilized.

Mathematical and graphical techniques have then made it possible to represent those SNA findings as a compact and systematic visual network description. In the Thirties, Jacob Moreno was the first to use visual images to display the patterning of linkages among social actors, with each actor being represented by a point and each link shown by a line connecting a pair of points. When sociologists applied this graphing technique, using colours, shapes, lines' thickness, node sizes and node relocation to visualise information on actors and their relations, they re-named those graphics sociograms.

Representing network information (relations among nodes) as a graph is therefore an extremely efficient form to describe a social structure, for it straightforwardly suggests some of the most important features of overall network structure. Apart from the visual focus, sociograms and associated network metrics allow exploring patterns of interaction, handling the complexity of social network data and understanding the construction and evolution of social structures.

3 MAPPING SNA TO ELICIT

In 1892, Durkheim said the essential is not the number of persons subject to the same authority but the number bound by some form of relationship (Breiger, 2004). Social network analysis enables access to this essence: the disciplined mapping of relations' patterning that create social structures. As an interdisciplinary behavioural science specialty, SNA defends that social actors are interdependent and that the links among them have important consequences for every individual. Those links permit the flow of information, affect, power, influence, social support and social control, they provide opportunities and, at the same time, potential constraints on individuals' behaviour.

On its own, ELICIT promotes a social structure. ELICIT is an experimentation platform that instruments the actions of a group of seventeen participants engaged in a situational awareness problem, with the goal to identify the who, what, when and where of a pending attack. Exploring the differences between different organisational structures, ranging from isolated to hierarchical and to edge organisations, the ELICIT participants build situational awareness by gathering and analyzing factoids and interacting with one another through factoids' sharing directly with each other or factoids' posting to websites. No participant is given sufficient information to solve the assigned problem without receiving information from others. Thus, interactions between and among participants are required by the ELICIT platform (Hayes and Hayes, 2008).

It is then possible to establish similarities between the ELICIT experiment and socio-centric networks, an expression of Russell Bernard’s to characterize actors in closed system networks (Kadushin, 2004). Considering the connectionist explanation as well as the structuralist approach, it is possible to visualise graphically and understand important tendencies arising from ELICIT experiments, for we benefit from most of the basic network measurements, measures of position, of connection, of cohesion and power, that enable the characterisation of how much, and in what ways, the seventeen players are embedded in relations.

In this context, a relevant part of the ELICIT’s SNA is dedicated to network governance, that is, to the network's own response to the environment uncertainty, the task complexity and the assets specificity (Jones, Borgatti and Hesterly, 1997). As we all are well aware of, the coordination of complex endeavours in uncertain and competitive environments is extremely difficult and informal social systems seem to respond better than bureaucratic structures (this assumption has been confirmed by several case studies analysed by NATO SAS-065 members in 2009 and 2010). Although not yet addressing a complex endeavour, the ELICIT experiment does provide elements to compare the performance of social systems upholding different organisational

structures. Whether hierarchical-oriented or edge-tailored the organisational structures embodied by the ELICIT experiments, understanding the information-seeking behaviours, the sources of decisions and the usage of information provides critical insight into ways to improve the ELICIT network's efficiency and effectiveness.

And this is exactly how network analysis has become relevant to management, how it is transforming how we study social relationships, how it can be used to understand how to improve networking and affect performance. Even the United States' Office of Force Transformation upholds social network analysis as one of the main concepts used to study the dynamics and personal interactions occurring in the battlefield, being its ultimate goal to understand its potential use in war and peacetime operations (Edison, 2005).

4 CONDUCTING SOCIAL NETWORK ANALYSIS IN ELICIT

ELICIT stands for Experimental Laboratory for Investigating Collaboration, Information Sharing and Trust and it is an investigation platform focused on the informational, social and cognitive impacts of the command and control approach space (allocation of decision rights, patterns of interaction and information sharing), comparing organisational structures within the context of information sharing, shared awareness and knowledge task. In this framework, it is important to recall the ELICIT's Information Value Chain: Networked organisations enable enhanced information sharing, which enables better situational awareness and improved shared awareness, which, on turn, results in increased effectiveness. This conceptual scheme directly derives from the fundamental aspects of Network Centric Warfare (NCW), namely the NCW tenets, the NCW Value Chain, the Command and Control (C2) Domains, the C2 Conceptual Research Model (CRM) and the C2 Approach Space. The NCW tenets (1999, Alberts et al) state that:

1. A robustly networked force improves information sharing.
2. Information sharing and collaboration enhance the quality of information and shared situational awareness.
3. Shared situational awareness enables self-synchronization.
4. These, in turn, dramatically increase mission effectiveness.

These tenets have been encapsulated into the SAS-065 Group's NCW Value Chain and are visible across the four C2 domains: the Physical (all entities are robustly networked), the Information (all entities have the capability to share, access, display, store, process and protect information), the Cognitive (each entity has the capability to develop high quality awareness) and the Social domains (encompassing the C2 processes and the interactions between and among individuals and entities). Based upon the NCW legacy, the SAS-065 Group is defining the NATO NEC C2 Maturity Model (N2C2M2), a framework capable of assessing organisations' C2 capabilities, through the definition of operational coherence (ability to generate synergy across organisations) towards the five NATO NEC operational capability levels and the possibility to associate the capability to adopt one or more C2 approaches with the different levels of C2 maturity: increased C2 maturity enables an organisation to adopt a wider range of C2 approaches. Table 1 presents the qualitative characterisation for each maturity level per C2 approach:

	ADR-C	PI-C	DI-C
Edge C2	Not Explicit, Self Allocated (Emergent, Tailored and Dynamic)	Unlimited Sharing as Required	All Available and Relevant Information Accessible
Collaborative C2	Collaborative Process and Shared Plan	Significant Broad Sharing	Additional Information Across Collaborative Areas/Functions
Coordinated C2	Coordination Process and Linked Plans	Limited Focused Sharing	Additional information about coordinated Areas/Functions
Deconflicted C2	Established Constraints	Very Limited Sharply Focused Sharing	Additional information about constraints and seams
Conflicted C2	None	No interactions across entities	Organic information

Table 1 – Qualitative Values for C2 Dimensions per Maturity Level

The NATO SAS-065 Group findings have thus supported that the N2C2M2 depicts as main assumption that more mature collective C2 Approaches (more distribution of decision rights across the collective, less constrained patterns of interaction and

broader dissemination of information) achieve higher levels of shared awareness and understanding which, in turn, result in increased endeavour effectiveness, efficiency (given effectiveness) and agility.

For the purpose of this work, it is especially the (social) networking of ELICIT experiments that will be explored, allowing the opportunity to observe relevant patterns of interaction (a key command and control factor) and of information sharing, the relative effectiveness of different organisational structures and the impact of influence and collaboration in social processes. Therefore, SNA is the scientific methodology chosen to assist in explaining ELICIT networking and patterns of interaction between the seventeen involved actors. The collected data of ELICIT runs and transaction logs shall be analysed based upon observations associated with metrics (direct when possible, indirect when needed) and network visualisation.

To conduct the exploratory SNA in ELICIT, it is important to establish correlations between the ELICIT collected data, the selected SNA metrics and indicators and the notable efforts towards understanding and modelling C2, published in Understanding Command and Control (Alberts & Hayes, 2006), in the NATO SAS-050 Final Report (SAS-050, 2006) and in the NATO SAS-050 Final Report (SAS-065, 2010). More specifically, SNA shall explore patterns of interaction, namely its sub-variables as defined by SAS-065 (cluster attractor, degree of inter-cluster connectivity and frequency or continuity of interaction). With respect to the selected SNA metrics and indicators, we shall highlight:

1. Node related:

- Node Degree – the number of nodes to which a node is adjacent or directly related to, composed of:
  - In-degree – number of ingoing links (also called Node Popularity);
  - Out-degree – number of outgoing links (also called Node Activity).
- Node Activity – number of times that the node's links have been used:
  - In-degree Activity – number of times ingoing links have been used;
  - Out-degree Activity – number of times outgoing links have been used.
- Node Betweeness – number of nodes that have a direct relation with nodes belonging to other circles;
- Node Centrality – a compound variable, measured by:
  - Node Degree;
  - Closeness – degree to which a node is close to all other nodes (see also Geodesic Distance);
  - Betweeness – frequency by which the node is located between pairs of other nodes.
- Node Geodesic Distance – shortest path between two nodes.
- Node Embeddedness – a compound variable, measured by:
  - Link Density – the relation between the node's links and the total number of links;
  - Link Strength – number of times a link has been used;
  - Link Flow – number of in-degrees and out-degrees of a node.
- Node Neighbourhood – number of adjacent nodes (dyads, if 2; Triads, if 3; Clusters, if more than 3).
- Node Path Length – number of nodes in path between two nodes.
- Node Reciprocity Index – level of reciprocating activity (replies to a link).
- Structural Holes – nodes in high risk of becoming isolated from the network.

2. Network related:

- Network Activity – number of times each link has been used;
- Network Mode Path Length – the mode of all nodes' path lengths;
- Network Balance – symmetry of connections (ingoing and outgoing) between nodes;
- Network Density – number of links in the network;
- Network Connectedness – capability of each node reaching all other nodes in the network;
- Network Diameter – maximum path within the network;
- Network Inclusiveness – relation between the number of isolated nodes and the total number of nodes;
- Network Clustering Coefficient – likelihood that two associates of a node are associates themselves;
- Network Structural Cohesion – minimum number of nodes that, if removed, the network collapses.

These quantitative measurements will be complemented with a qualitative analysis, giving insights on the content and nature of nodes' and the network's interaction. Part of this supportive analysis will refer to a new ELICIT software analysis application (Manso, 2009), which provides charting, tables and relevant information concerning the sharing activity, the quality of information position, information awareness and understanding, as well as measures of effectiveness and efficiency.

4.1 Early Expectations

Considering the concepts and definitions presented herein, whether concerning C2 literature, whether referring to the SNA methodology, we shall essay to observe in ELICIT experiments the following early expectations:

SNA Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
Node Centrality	From VERY LOW (isolated node) to HIGH (central node sets) and to MEDIUM (decentralised network)
Node Embeddedness	From LOW (low density) to HIGH (high density) and to MEDIUM (distributed density)
Network Activity	From LOW (minimal degrees) to MEDIUM (limited degrees) and to HIGH (multiple degrees)
Network Path Length	From HIGH (first order zone) to LOW (hierarchical rules) and to LOW (geodesics)
Network Diameter	From LOW (adjacency) to MEDIUM (hierarchical setting) and to LOW (wider neighbourhood of geodesics)
Network Inclusiveness	From LOW (one isolate) to NOT APPLICABLE (no isolates) and to MEDIUM (isolated node behaviour)
Network Clustering Coefficient	From HIGH (small node sets) to LOW (rigid node association) and to VERY LOW (free node association)
Network Connectedness	From LOW (minimum node reach) to MEDIUM (limited node reach) and to HIGH (full node reach)
Network Structural Cohesion	From LOW (small network cohesion) to VERY LOW (minimum network cohesion) and to HIGH (high network cohesion)

Table 2 – Expected SNA Variable Behaviour from Less Mature to More Mature C2 Approaches

4.2 The N2C2M2 ELICIT Experiments

At the core of the N2C2M2 ELICIT experiments is the experimental design of the ELICIT platform, implemented by Marco Manso (Manso, 2009), which recreates each of the collective command and control approaches that correspond to different level of C2 maturity described in the N2C2M2. To best capture the N2C2M2 model, the experimental design required modifying the ELICIT baseline organizational specifications, so that the conditions for each organizational model to operate at a specific collective C2 approach would be in place.

Still, it was maintained the ELICIT scenario of an imminent terrorist attack, with related information being provided to each of the seventeen individuals, so that no individual or team possesses sufficient information to accomplish the task of identifying the "who", "what", "where" and "when" of the attack, within a specific timeframe. Only through sharing information (factoids), would the task be accomplished.

In what concerned the modeling of the Conflicted collective C2 approach in the ELICIT experiments, it is assigned one isolated Coordinator and four isolated teams (one for each "w" of the problem), composed of four elements, being one the team leader. Acting independently, each team focus on its specific problem space (the assigned team's "w"), whereas the isolated Coordinator deals with the whole problem (the four "ws"), without the possibility of interacting with the teams and their websites (the coordinator depends solely on the factoids received from the server). Mission is accomplished if each team leader determines his or her team's correct solution to the respective problem space, with overall organization success depending on whether all teams reach the correct problem solution.

The next collective C2 approach modelled was the Deconflicted. In this case, there are one Deconflictor and four teams (one for each "w" of the problem), composed of four elements, including the team leader. It is possible the communication or factoid sharing between each of the four team leaders and the Deconflictor, and among team members, creating this limited, vertical peer-to-peer interaction along stove-piped chains of command. Partitioning the problem space among the four teams helps to avoid the negative cross-impact of the previous model, what may be perceived as the genesis of collective command and control. Still, dealing with its own problem space (the specific "w"), each team pursues independent goals, being successful when the team leader determines the correct solution to the team's problem space. Theoretically, overall organization success will be achieved as all teams find the correct solution.

The Coordinated collective C2 approach is played by one Coordinator and four teams (one for each "w" of the problem), composed of four elements, including the team leader. It is possible the communication or factoid sharing between each of the four team leaders and the Coordinator, and among team members, with the opportunity to generate synergies and combine

resources to meet effective goals. Likewise, the Coordinator has access to all four websites, and he works on the overall problem space dimensions for the organization's success depends on the Coordinator finding the correct solution.

The fourth collective C2 approach modeled was the Collaborative one, with a Facilitator and four teams (one for each "w" of the problem), composed of four elements, including the team leader. Communication or factoid sharing is available to all participants, being also possible to attach to each shared or posted factoid the relevance and the trustworthiness indicators, in what preconfigures the catalytic environment for increased interaction and improved shared awareness. Organizational success depends upon the Facilitator finding the correct solution to all problem spaces or the team leaders finding the correct solution to their respective problem space.

Finally, Edge is the fifth collective C2 approach modelled to ELICIT. Illustrating close working entities that are able to identify and implement the best collective C2 approach to meet the challenge, this design depicts a flat organization of seventeen participants, involved in a widespread rich information sharing, so that each participant may find the correct solution to the overall problem space dimensions.

To implement the SNA analysis, it were considered a set of ELICIT runs. Their list is presented in the following table:

Run	Date	Log File	C2 Approach	Factoid Set
L1 01	13-05-2009	20090513-1053-21812-group_1_CONFLICTED.log	CONFLICTED	4
L1 02	28-05-2009	20090528-1246-32783-group_1_CONFLICTED.log	CONFLICTED	1
L1 03	03-06-2009	20090603-1135-40719-group_1_CONFLICTED.log	CONFLICTED	3
L2 01	29-04-2009	20090429-1308-24386-group_1_B.log	DECONFLICTED	1
L2 02	29-04-2009	20090429-1402-18407-group_1_B.log	DECONFLICTED	4
L2 03	12-05-2009	20090512-1511-12023-group_1_DECONFLICTED.log	DECONFLICTED	1
L2 04	02-06-2009	20090602-1413-19588-group_1_DECONFLICTED.log	DECONFLICTED	3
L3 01	07-05-2009	20090507-1413-26985-group_1_COORDINATED.log	COORDINATED	1
L3 02	13-05-2009	20090513-1142-59475-group_1_COORDINATED.log	COORDINATED	3
L3 03	03-06-2009	20090603-1212-12301-group_1_COORDINATED.log	COORDINATED	2
L3 04	03-06-2009	20090603-1332-06152-group_1_COORDINATED.log	COORDINATED	4
L4 01	06-05-2009	20090506-1133-24903-group_1_COLLABORATIVE.log	COLLABORATIVE	1
L4 02	06-05-2009	20090506-1225-19696-group_1_COLLABORATIVE.log	COLLABORATIVE	4
L4 03	12-05-2009	20090512-1415-19171-group_1_COLLABORATIVE.log	COLLABORATIVE	3
L4 04	02-06-2009	20090602-1515-03801-group_1_COLLABORATIVE.log	COLLABORATIVE	2
L5 01	29-04-2009	20090429-1101-06528-group_1_A.log	EDGE	1
L5 02	29-04-2009	20090429-1152-08894-group_1_A.log	EDGE	4
L5 03	07-05-2009	20090507-1500-37261-group_1_EDGE.log	EDGE	4

Table 3 – ELICIT Experiment Runs

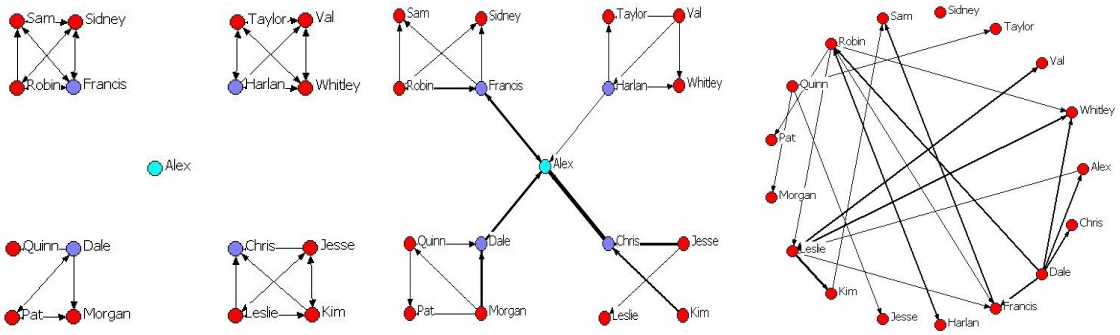
4.3 SNA Findings in the N2C2M2 ELICIT Experiments

Network analysis and the production of social science data involve a process of interpretation. To carry out such interpretation robustly it is understood that it is imperative to conduct more runs to verify these first SNA findings. Additionally, it is important to recall that, otherwise stated, for analysis purposes, the interaction measures observed the strict sharing behaviour, being therefore excluded every resource to websites.

Node Centrality

The proposition that an actor's position in a network has consequences for the actor as well as the network has occupied a central place in network thinking. Networks are understood as the actor's environment for action, source of behavioural opportunities and constraints, and the structure of ties inherent of the actor's location pinpoint which are the key players, the individuals best connected or that have most influence. This is the very core of **centrality**'s issues, first introduced by Bavelas in 1950.

Extracted from ELICIT runs, the following sociograms illustrate how a node occupies a **central position** within a network. In L1 Conflicted, the centrality levels are extremely reduced for the network is broken in five isolated blocks. In L3 Coordinated, centrality is a major element, since communication among the different teams flows through intermediary central nodes (the four team leaders and the Isolated Coordinator). In L5 Edge, centrality is no longer a relevant element, since all nodes are quite able to reach each other directly.



L1 01 Sociogram **L3 03 Sociogram** **L5 02 Sociogram**

Figure 1 – ELICIT Runs Set of Sociograms

Centrality has been used to determine group activity and efficiency in problem-solving and the perception of leadership, becoming such an important SNA variable that three competing conceptual constructions essay to explain how centrality affects group processes: the first is centred in communication activity (**degree** measure), the second is focused in the control of communication (**betweeness** measure) and the last is based on efficiency (**closeness** measure). Centrality as activity is measured in degrees, that is, the number of connections an actor or node has, being it outward and, therefore, expressing the actor's influence, or inward, displaying the actor's prominence (status). Centrality as control derives from the frequency with which a node falls between pairs of other nodes on the shortest path connecting them, a strategic location on communication paths that can influence the whole group by facilitating, impeding or biasing the transmission of information. Finally, centrality as independence or efficiency derives from the ability of a node to be close to all other nodes in the network, avoiding the potential control of other relayers or intermediaries and therefore reaching a certain level of independence. At the same time, because that node is close to all other nodes, this particular central node may reach the entire network in minimum time or cost, achieving what Beauchamp called in 1965 the *optimum efficiency* in communication.

For analysis purpose, ELICIT collected data on centrality is based on the average for the three centrality node measures of each of the C2 maturity levels:

Node Centrality			
	Betweenness	Degree	Closeness
Average L1	0,196	2,529	2,627
Average L2	16,059	2,735	6,946
Average L3	15,857	2,912	7,081
Average L4	3,154	2,132	7,223
Average L5	5,059	2,745	6,363

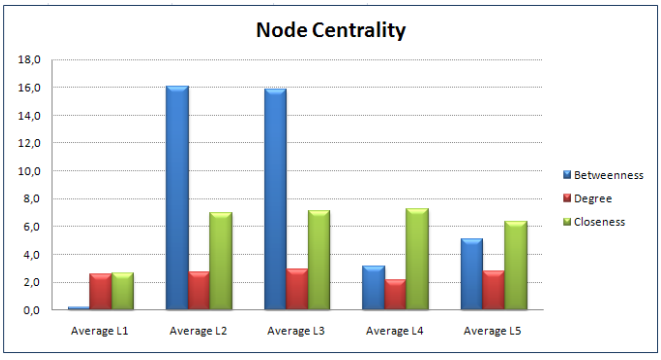


Figure 2 – ELICIT Node Centrality Measures

The higher the number of degrees, the betweeness and the closeness of a network, the higher its centrality score. We may observe that the **number of degrees** is the measure that varies the less amongst all C2 maturity levels, indicating that whether by playing a role that enforces a connectionist approach (L2 Deconflicted and L3 Coordinated) by connecting more to more

nodes (L4 Collaborative and L5 Edge), neighbourhood has basically the same relative importance as the expression of an active participation in the ongoing communication process.

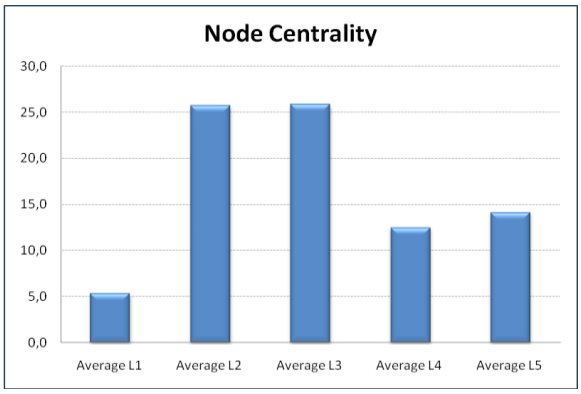


Figure 3 – ELICIT Node Centrality

By contrast, **betweeness** is the centrality measure that exhibits the largest difference amongst the C2 maturity levels, obviously achieving minimum values in the L1 Conflicted (due to the five separate organisational blocks) and reaching the highest values for the L2 Deconflicted and L3 Coordinated approaches (richer in roles that influence information flows and are failure points to communication). Nodes with high betweeness are sensitive to their roles as brokers of vital information to the problem's solution. To the extent that each node passes information and contributes to the solution, it is expected to be satisfied: thus, the greater the betweeness, the greater the sense of participation and influence (Freeman, 1977). The Facilitator of L4 Collaborative gives way to the dilution of node centrality over a larger and more highly connected network, whereas the L5 Edge environment promotes both direct connections and the emergence of (central) prominent individuals that affect interaction patterns, leaving less room to intermediary roles. On its hand, **closeness** reflects the network's compactness, thus being extremely low for the L1 Conflicted, then increasingly rising from L2 Deconflicted through L4 Collaborative (the presence of organisational rules determines shorter paths between nodes) and again lowering in the L5 Edge where self-arbitrary activity encourages unnecessary redundant connections.

It is also important to note that L1 Conflicted, L2 Deconflicted and L3 Coordinated have small differences between minimum and maximum values for the degree and closeness measures, whereas for the betweeness measure (L2 Deconflicted and L3 Coordinated) the difference is about two figures, exactly the same difference found for the L4 Collaborative and L5 Edge degree measures. This means that the average found displays a consistent result from the different runs on the specific maturity level. Where the results suggest a wider variation (especially measures betweeness and closeness for L4 Collaborative and L5 Edge), the drawing of conclusions is extremely dependent on the runs carried out, for additional testing is advised.

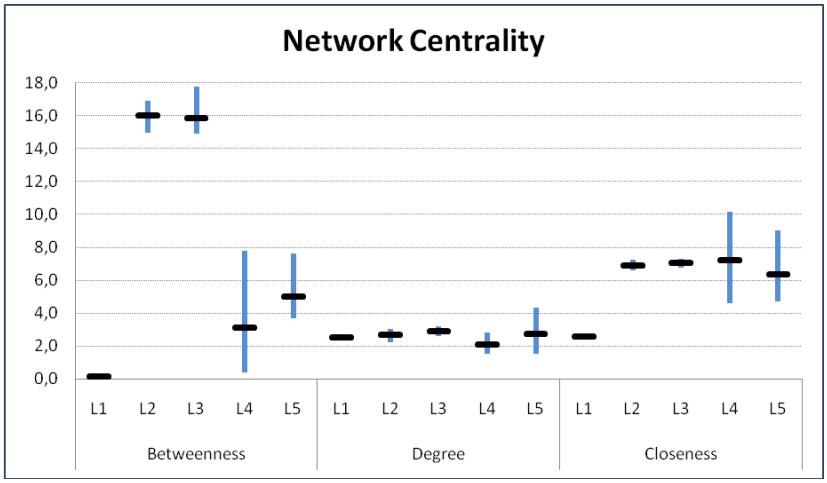


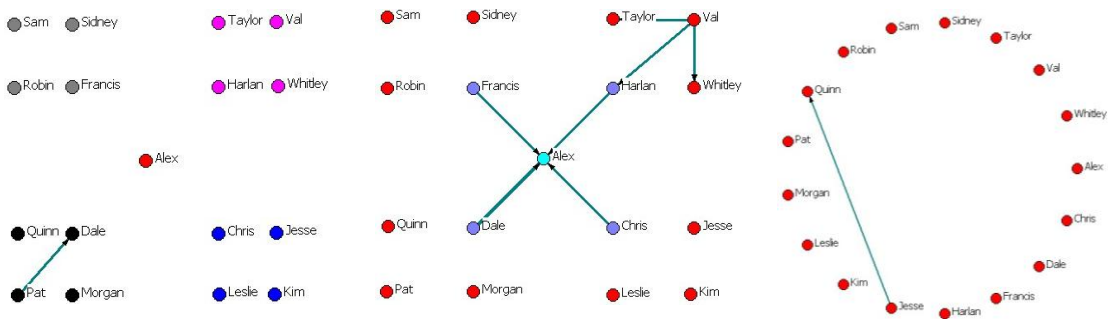
Figure 4 – ELICIT Network Centrality

Overall, summing the three measures of the compound variable **Centrality**, we see that its behaviour goes from **Very Low** (based on centrality from four different components and not a single network) to **High** (influenced by the extremely high levels of betweeness) and to **Medium** (the decentralised resilient network prevails), as we progress from less mature to more mature C2 approaches.

Node Embeddedness

With an economic genesis, the **embeddedness** theory advocates the primacy of economic performance based upon the number of connections and the frequency of interactions that guarantee competitive advantage. Responsible for the texture in social structures, embedded ties soon became important in explaining performance benefits, a useful relational approach that also applies to SNA, being anchored in the **link density** (the relation between the node's links and the total number of links), **strength** (number of times a link has been used) and **flow** (number of links established by a node) measures, which are key indicators to determine how individuals explore their neighbourhood to surpass difficulties and maximise opportunities.

Extracted from ELICIT runs, the following sociograms illustrate how **link strength** (namely over five connections) is manifested in networks. In L1 Conflicted, the isolation between subgroups promotes strong bonding only within those same subgroups. In L3 Coordinated, vertical differentiation is closely accompanied by strong connections, for the intermediary elements are essential for the network's information flow. In L5 Edge, the diversity of information sources hampers the need to establish strong ties.



L1 02 More than 5 Link Strength Connection | **L3 01 More than 5 Link Strength Connection** | **L5 03 More than 5 Link Strength Connection**

Figure 5 – ELICIT Runs with Strongest Connections

ELICIT collected data on embeddedness exhibits similar distribution behaviour for all ELICIT runs, so it was determined the average for the three embeddedness measures for each of the C2 maturity levels:

Node Embeddedness			
	Link Density	Link Strength	Link Flow
Average L1	0,196	2,529	2,627
Average L2	0,549	7,397	25,750
Average L3	0,659	5,647	17,176
Average L4	0,143	2,029	7,529
Average L5	0,208	1,392	7,176

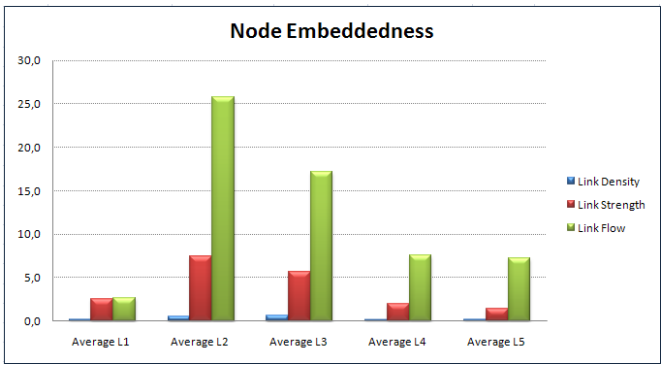


Figure 6 – ELICIT Node Embeddedness Measures

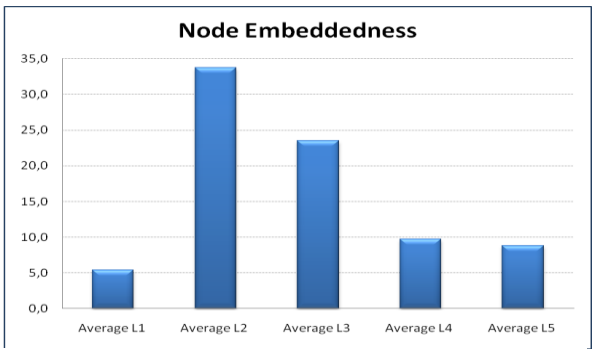


Figure 7 – ELICIT Node Embeddedness

The more embedded networks are, the higher their links' density, strength and flow accounts. We may observe that **density** is the measure that varies less amongst all C2 maturity levels, indicating that whether by constraint of the number of neighbours (L1 Conflicted, L2 Deconflicted and L3 Coordinated) or variety of sources of information (L4 Collaborative and L5 Edge) there was not a significant sharing activity in the communication process. In what concerns **link strength**, repeated interactions were obviously higher in the presence of unequal rankings (L2 Deconflicted and L3 Coordinated) than in the face of a wider and looser network (L4 Collaborative and L5 Edge), reminder of the importance of Granovetter's 1973 weak ties' strength theory to the pursuing of novel information and knowledge. Looking at the total number of connections established (**link flow**), again it is visible the relative hegemony of social structures organised in small closed groups (L2 Deconflicted and L3 Coordinated), where the frequency of involvement empowers the share of understandings (the down side of this contagion phenomenon is the greater likelihood of biased critical decisions by virtue of repeated information received throughout the ELICIT experiments). By contrast, in the L4 Collaborative and L5 Edge approaches,

it is possible to discover the teachings of Duncan Watts and Doug White (Hanneman and Riddle, 2005) concerning the relation between the actors' connections and the exposition to more information, a necessary condition to fulfil ELICIT's goal. Still, in L5 Edge, this opportunity to *navigate* through the network, sharing information and exercising influence, is balanced with the cost effectiveness of such bridging behaviour, contributing to the overall reduction of the network's connections.

In network embeddedness, there is not significant variation between maximum and minimum levels for the link density and strength measures, indicating that conclusions drawn are well supported. The same cannot be said about the link flow measures, with high variations, especially for L1 Conflicted, L2 Deconflicted and L3 Coordinated C2 maturity levels. Nevertheless, these findings make it quite visible to understand why hierarchical organisations, with differentiated and ranked individuals, are a common form of embeddedness in social structures.

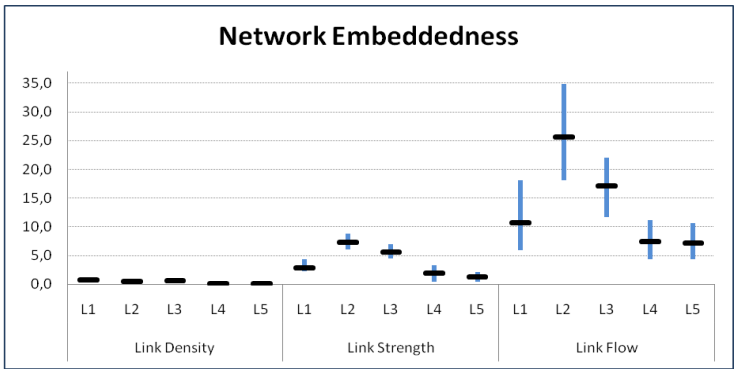


Figure 8 – ELICIT Network Embeddedness

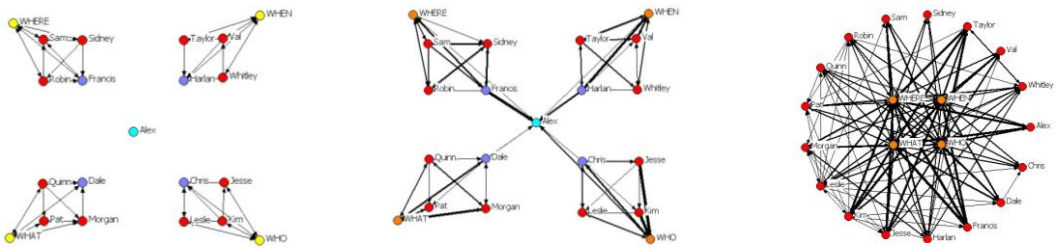
Overall, summing the three measures of the compound variable **Embeddedness**, we see that its behaviour goes from **Low** (based on the low connection density of isolated components) to **High** (influenced by the extremely high levels of link flows and strength and network density) and to **Medium** (based upon the weak ties recognition of their competitive advantage as independent information seekers), as we progress from less mature to more mature C2 approaches.

Network Activity

The SNA analysis follows Snijders' actor-oriented model in the sense that, apart from specific organisational constraints, each actor determines his or her outgoing ties on their own pursuit of a rewarding pattern of relationships, a pursuit that is reflected on the actor's **activity** in the network. Nevertheless, it also presents a certain level of chance, since information seekers have no control over the quality of the responses nor information communicators have assurance that the answer provided will be understood or reciprocated. Therefore, nodes have **agency**, the ability to use all available resources to optimise his or her position in the network and maximise the production of network effects (popularity, reciprocity, transitivity and balance).

The position in the network certainly is a function of the relationships to others, giving way to the concept of role that incurs not only in a specific behaviour but also influences additional interaction patterns, for an ego only is if an alter exists. As an endogenous process, the network dynamically evolves based on **degree activity**, expression of social participation and selection, that is, the inward and outward links among the nodes, which also reflect each node's relevance or status, in a struggle to achieve added-value network configurations. In turn, these network mechanisms are themselves responsible for the nodes' specific location in the network.

Extracted from ELICIT runs, the following sociograms illustrate the activity generated in three ELICIT runs. This activity is comprised of all available interactions, including the sharing, posting and pulling activity, as well as the adding of factoids and the identification attempts. In L1 Conflicted, the isolation between subgroups constrains the network's activity. In L3 Coordinated, the need to obey to a hierarchical communication path influences the network's activity. In L5 Edge, the diversity of information sources reinforces the network's activity level.



L1 03 Sociogram with websites **L3 04 Sociogram with websites** **L5 03 Sociogram with websites**

Figure 9 – ELICIT Sociograms with Websites

The identification of key players is a clear example of compromise between network position (formal authority) and organisational participation (**social activity**). Key players become then those that exhibit high social capital, the ability to draw on the network resources to reach, maintain and maximise significant outcomes such as power, leadership or performance. And if this exercise reveals the value of connections, it certainly does not neglect Burt's structural holes mechanism (1992) of delivering positive results to those displaying poor connections.

ELICIT collected data on the average network activity for each of the C2 maturity levels reveals:

Network Activity	
Average L1	291
Average L2	525
Average L3	412
Average L4	711
Average L5	981

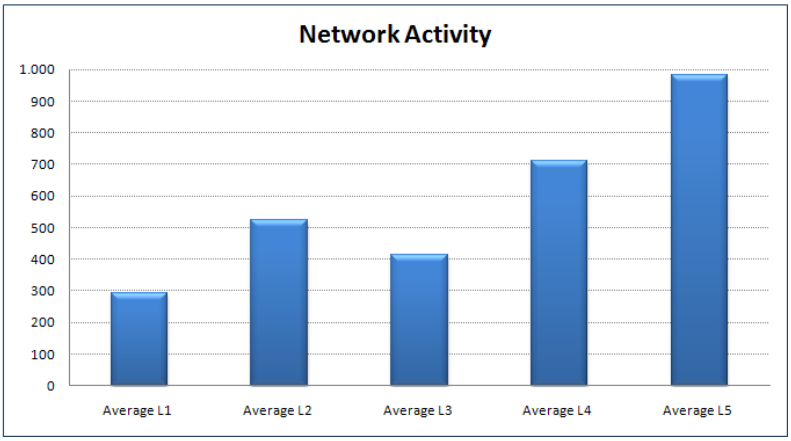


Figure 10 – ELICIT Network Activity

The higher the value of **network activity** is, the more dynamic and participative it is. We may observe that L1 Conflicted presents a low activity figure, mainly conditioned by the five network components' isolation. With the withdrawal of this isolation factor, the activity rate rises in L2 Deconflictor and L3 Coordinator, despite the fact that this particular approach shows a relative decrease caused by a tight organisational structure enforcing geodesic paths and ignoring what is past the first order zone. Expectedly, L4 Collaborative and L5 Edge display the highest scores in network activity, with the emphasis on the most mature level: the possibility to establish transitive links, access diversified resources, fight for independence and participate in the decision-making process encourages social participation.

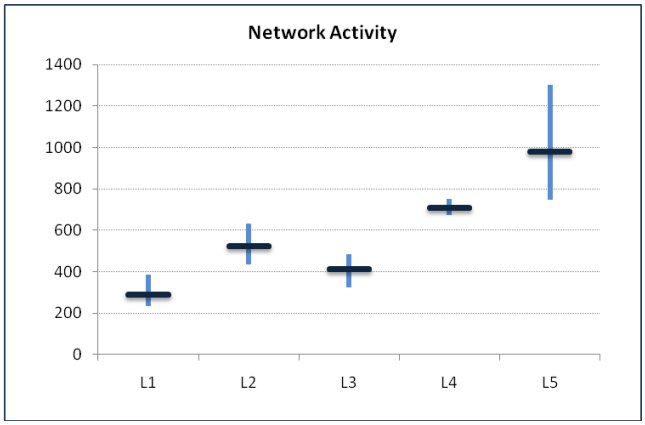


Figure 11 – ELICIT Network Activity

The **network activity** results for the five C2 maturity levels portraits a steady increase of about 200 interactions from level to level, with the exception of L3 Coordinated, showing a slight reduction on connections. It is also worth mentioning that the minimum activity level for L5 Edge is basically the maximum activity value for L4 Collaborative, exposing a large increase of activity levels. The fact that L5 Edge minimum and maximum activity value varies from 747 e 1301 interactions is also an indicator that more tests should be run to reinforce these conclusions' robustness.

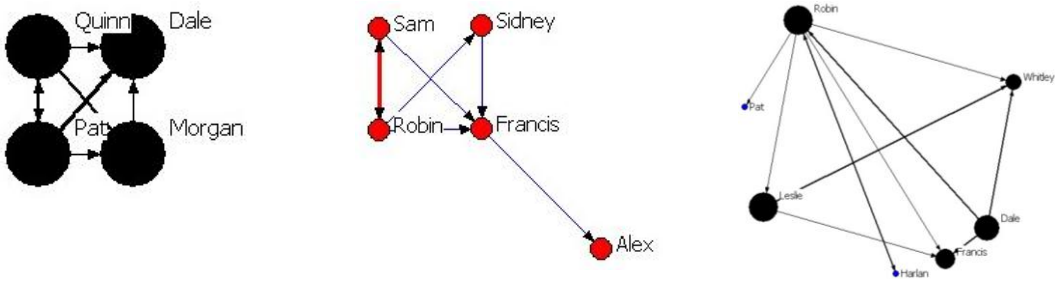
Overall, the **Network Activity** variable indicates an evolution from **Low** (based on the restricted social participation of isolated components) to **Medium** (constrained by the hierarchical positions and relations) and to **High** (promoted by the opportunity to make larger egonets, develop a social selection process and contribute to the community's goal), as we progress from less mature to more mature C2 approaches.

Network Path Length

A network's structural conditions affect the flowing of information throughout the network. The most relevant of its conditioning elements is the **path length**, or the distance between pairs of nodes in the network. In this context, if the length of the shortest path between a pair of nodes is high, information takes longer to reach the entire network. Additionally, the most

efficient link between two nodes is the shortest path between them, that is, their geodesic path. But it is not only the pathways length that matters, for also the number of paths is decisive to understand networks' behaviour and potential: networks with few connections tend to disaggregation, whereas more and adjacent connections indicate robustness, flexibility and the ability to act swiftly. Through the pathways, nodes seek opportunities, exert influence and share information, and each transaction made sustains a specific cost that, in more dense networks, may degenerate in obsessing behaviour towards sharing, in constantly receiving the same information or contradictory information and even in information overload.

Extracted from ELICIT runs, the following sociograms illustrate different path lengths generated in three ELICIT runs. In L1 Conflicted, Dale's egonet illustrates a small set of nodes that has seven path lengths, all with no intermediaries. In L3 Coordinated, Francis' egonet displays his intermediary role to deliver information from own team to Alex. In L5 Edge, Robin's egonet shows the establishment of several connections in the pursuit of novel information.



L1 02 Dale's Egonet **L3 02 Francis' Egonet** **L5 02 Robin's Egonet**

Figure 12 – Examples of Egonets in ELICIT

ELICIT collected data on **network average path length** for each of the C2 maturity levels shows:

Network Average Path Length	
Average L1	0,138
Average L2	0,960
Average L3	0,545
Average L4	0,430
Average L5	0,561

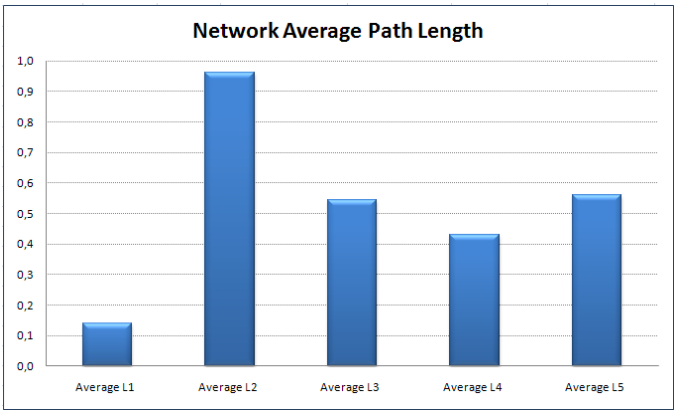


Figure 13 – ELICIT Network Average Path Length

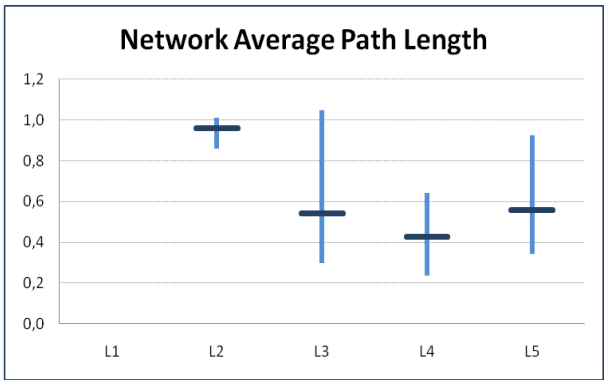


Figure 14 – ELICIT Network Average Path Length

We may observe that, across the different C2 maturity levels, the range of **path lengths** remains extremely low (between 0 and 1, that is, varying from no intermediary to one intermediary), a consequence of the somehow small network of seventeen individuals and of the organisational rules in certain levels. L1 Conflicted presents a very low path length derived from the five network components' isolation and is not considered for analysis. L2 Deconflicted and L3 Coordinated present higher path length levels reflecting a larger network and its hierarchical ruling. Expectedly, L4 Collaborative and L5 Edge display the lowest path lengths, in the first level still encouraged by the dependence on teaming and localised decision-making prerogatives and, in the latter, provoked by the availability of geodesics to an increased number of information sources and the requirement for

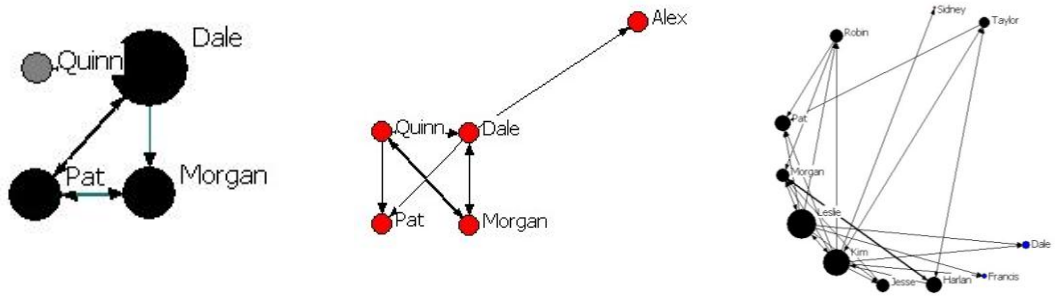
independence. The average network path length for the considered C2 maturity levels shows that the variation between minimum and maximum values is larger in L3 Coordinated and then in L5 Edge, suggesting the need for more testing to corroborate the findings.

Overall, the **Network Path Length** variable indicates an evolution from **High** (based on the possibility to interact within the first order zone) to **Low** (constrained by the hierarchical positions and relations) and to **Low** (enabled by proliferation of geodesic connections), as we progress from less mature to more mature C2 approaches. It was expected that L5 Edge would present lower path length values, due to the absence of imposed communication paths. Still, it was not the case and further testing is advised on this matter.

Network Diameter

The importance of the timing of information flow throughout a network is understandably an important issue in organisational management. In this framework, just as relevant as the geodesics, is the **diameter of the network**, that is, the length of the longest geodesic path between two nodes, also called eccentricity. If the shortest path length determines the efficiency of the connection, the measure of the network's diameter indicates the speed of spread of the same information across the entire organisation, leading to what is usually known as the contagion phenomenon: the adoption of shared knowledge and ideas through interaction. The distribution of information will thus be hampered in networks exhibiting large diameters or long geodesic paths.

Extracted from ELICIT runs, the following sociograms illustrate different path lengths generated in three ELICIT runs. In L1 Conflicted, Dale's egonet illustrates a small set of nodes that constructs a cluster with six path lengths and where Quinn is a pendant and Morgan's information reaches Dale indirectly, through Pat. In L3 Coordinated, Dale's egonet displays his intermediary role to deliver information from own team to Alex. In L5 Edge, Robin's egonet shows the establishment of several connections in the pursuit of novel information.



L1 01 Dale's Egonet **L3 04 Dale's Egonet** **L5 01 Kim's Egonet**

Figure 15 – Examples of Egonets in ELICIT

ELICIT collected data on network path length enables the extraction of the network diameter value for each of the C2 maturity levels:

Network Average Path Lengths					
Path Length	L1	L2	L3	L4	L5
0	29,0	25,8	33,3	26,3	26,3
1	3,0	29,8	17,8	14,5	20,0
2	0,3	29,0	10,0	3,3	11,0
3	-	1,5	0,8	-	0,3

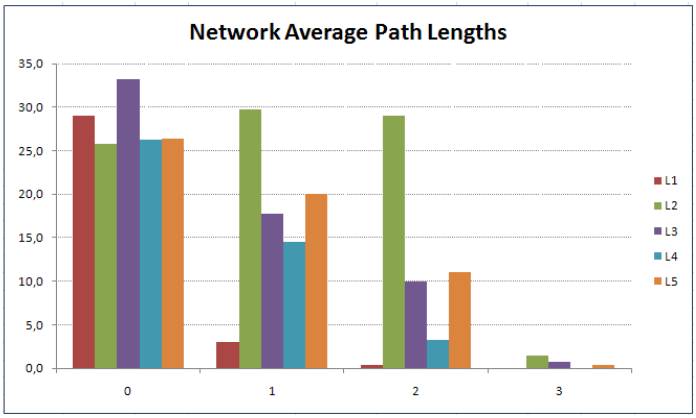


Figure 16 – ELICIT Network Average Path Lengths

We may observe that, across the different C2 maturity levels, the **network diameter** figure never surpasses path lengths of three, still considered as an indicator of short diameter networks. L1 Conflicted is extremely concentrated in direct connections, notably because of the isolated small blocks of nodes. L2 Deconflicted and L3 Coordinated expose hierarchical organisations that reach the highest network diameter, reflecting a vertical differentiation of three ranking levels. Also L4 Collaborative has a network of the third order zone, clearly showing a hierarchical functioning, whereas L5 Edge regains a wider diameter, with a regular distribution of connections through path lengths 0 to 2 and a very low occurrence of path length 3 connections, reinforcing that although no ruling exist to observe formal chain of communication, the freedom to perform social activity and selection stimulates a denser network. Social mechanisms like unrestricted access and reputation contribute thus to reduce transaction costs, gain comparative advantage and promote the emergence of network governance. It is then admissible to consider that, without those social mechanisms, collaboration would hamper and networks would collapse.

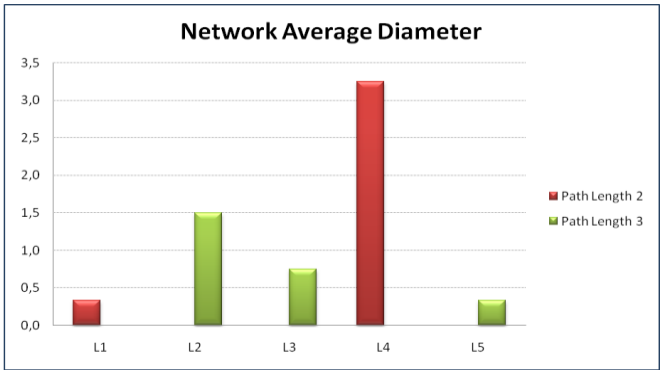


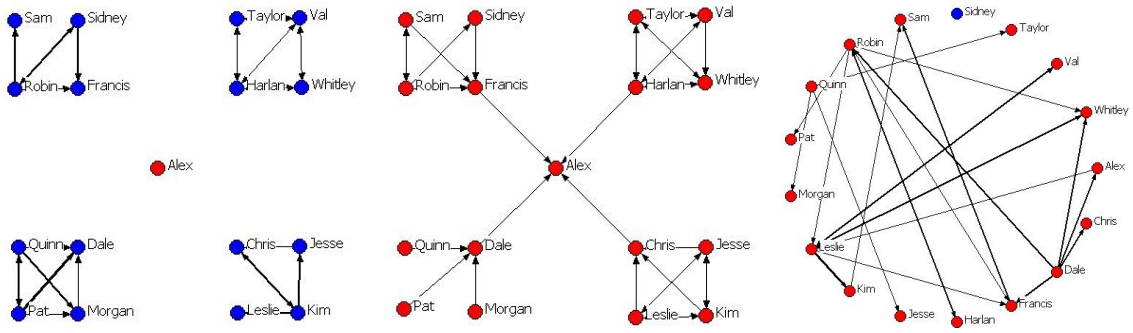
Figure 17 – ELICIT Network Average Diameter

The **Network Diameter** variable presents the largest path length for each of the C2 maturity levels, that is, path lengths of 2 for L1 Conflicted and L3 Coordinated and path lengths of 3 for L2 Deconflicted and L3 Coordinated and L5 Edge. Overall, the Network Diameter variable indicates an evolution from **Low** (proliferation of adjacency leads to small figure in path length 2) to **Medium** (social stratification is based on a network of three layers) and to **Low** (large neighbourhood explores the third zone order although it is not a robust tendency), as we progress from less mature to more mature C2 approaches.

Network Inclusiveness

In 1934, Mead established the theoretical basis to understand the creation of knowledge as a social process. Leveraged by their individual social capital, nodes interact and share ideas, information, and opinions across the network, in a process influenced by the ties' density and strength and the network's geodesics and diameter. A third element that is also present and influential is the **network's inclusiveness parameter** (the total number of nodes minus the number of isolates), that is directly related with the density of the network and the speed at which information flows among the nodes.

Extracted from ELICIT runs, the following sociograms indicate how many isolates exist in the network. In L1 Conflicted, Alex is the sole isolated node. In L3 Coordinated, there is no isolate, for the hierarchical structure prevents it. In L5 Edge, the freedom to establish connections does not encourage isolationist behaviour; in this example, there is an isolate (Sidney) that preferred to use websites' information instead of sharing.



L1 02 Isolates **L3 02 Component** **L5 02 Isolates**

Figure 18 – Isolates in ELICIT Runs

Therefore, the denser is the network, the more inclusive it is, and this is valid despite the variation of their degree of connection, for the actual number of links also affects the density of the network.

Network Inclusiveness	
Average L1	0,058
Average L2	-
Average L3	-
Average L4	0,191
Average L5	0,147

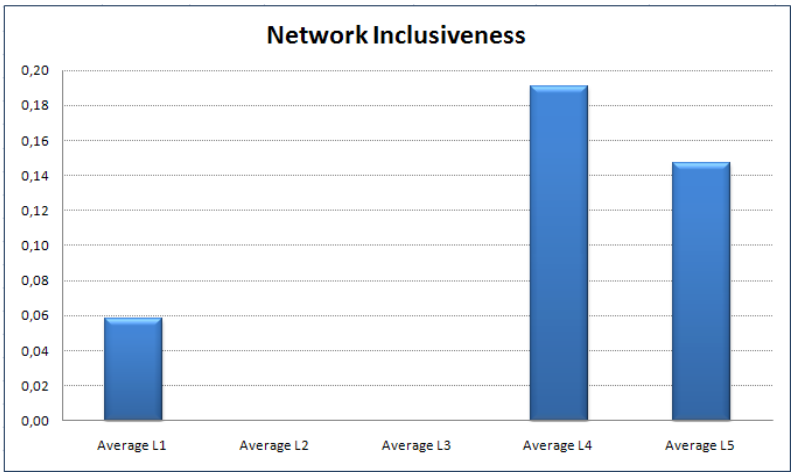


Figure 19 – ELICIT Network Inclusiveness

ELICIT collected data on the average **network inclusiveness** of each C2 maturity levels indicates that L1 Conflicted, although a network of four isolated key cores, was in fact considered as network with a sole isolated node (the Isolated Coordinator), reason why it presents an extremely low relation between the networks' total number of nodes and isolates. In L2 Deconflicted and L3 Conflicted, the structured organisational ranking does not allow for isolationist behaviours, so there is no inclusiveness applicable for those organisations. In the last two C2 maturity levels, the network inclusiveness index increases to accommodate the nodes' that prefer to base their information-seeking behaviour on website pulling rather than the sharing activity. Nevertheless, because of the nature of the experiment and of the limited network's number of nodes (seventeen), the presence of isolates would never be quite significant. It is important to refer that network inclusiveness maximum and minimum levels for L4 Collaborative and L5 Edge vary proportionately. Thus, the average figure characterises well the reasoning involved.

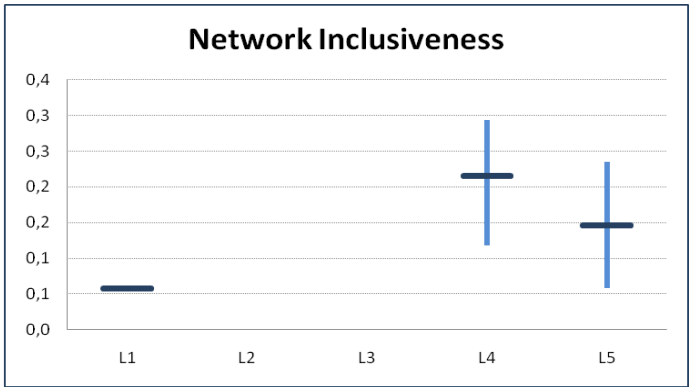


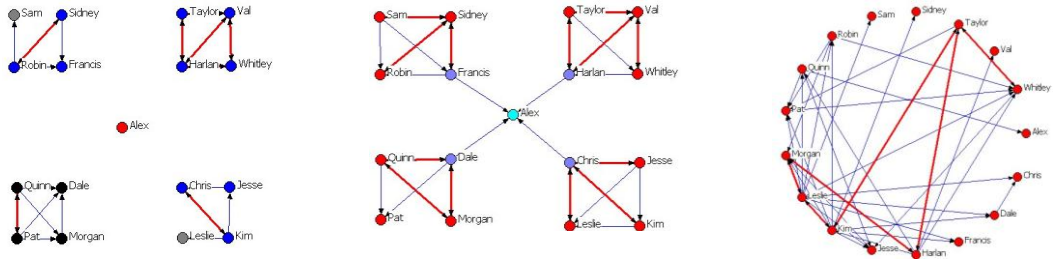
Figure 20 – ELICIT Network Inclusiveness

Overall, the **Network Inclusiveness** variable indicates an evolution from **Low** (based on the presence of a single isolated node pre-determined by ELICIT rules) to **Not Applicable** (hierarchical structures show high levels of cohesion with no isolated nodes) and to **Medium** (the availability of information on websites and the will for independent action favour the tendency to behave in isolation), as we progress from less mature to more mature C2 approaches.

Network Clustering Coefficient

Traditionally, social structures are based upon individuals' interactions that embed them into dyads (relation of adjacent nodes), triads (relation of three nodes) and **clusters** (relation of three and more nodes, where two associates of a node are associates themselves). The clustering analysis is therefore a very useful method to analyse social structures and benefits of path length information and egonets design. Establishing patterns of interaction in ELICIT helps to yield special insights about social structures. The level of reciprocity and balance in relations can be understood as a token of stability of the actor's position as much as an indicator of its degree of vulnerability, dependency and cohesion.

Extracted from ELICIT runs, the following sociograms demonstrate the establishment of reciprocated ties, indicating a stronger bonding or connection between two nodes. In L1 Conflicted, each small cluster of nodes within the network crafts stronger bonding that may be exclusive of two nodes or not. In L3 Coordinated, the presence of reciprocated ties is high, highlighting a robust and cohesive network. In L5 Edge, reciprocated ties are not a structural element but they contribute to the presence of a cohesive, clustered network.



L1 02 Reciprocal Ties **L3 04 Reciprocal Ties** **L5 01 Reciprocal Ties**

Figure 21 – Reciprocal Ties in ELICIT Runs

ELICIT collected data on the average **network clustering coefficient** for each C2 maturity levels indicates that L1 Conflicted scores the highest clustering coefficient, since its organisation structure is compounded of four isolated key cores with four elements each and one isolated node. In L2 Deconflicted, the Deconflictor's role borrows a new dynamic into inter-team activity and determines the reduction of the network clustering level, which again rises in L3 Coordinated due to the hierarchical structure. In the last two C2 maturity levels, the network clustering coefficient decreases with the opportunity to actively diversify on information sources. Concerning the data collected for the networks' **clustering coefficient**, it is important to highlight that, although there were always some small variation between the maximum and minimum levels for each particular C2 maturity level, that variation was accentuated in L5 Edge (variations of nearly 0,20), a situation that indicates the relevance of performing additional testing on this matter.

Network Clustering Coefficient	
Average L1	10,00
Average L2	8,50
Average L3	10,25
Average L4	8,25
Average L5	8,67

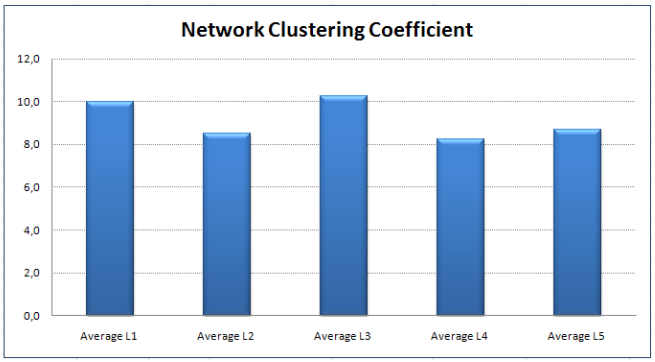


Figure 22 – ELICIT Network Clustering Coefficient

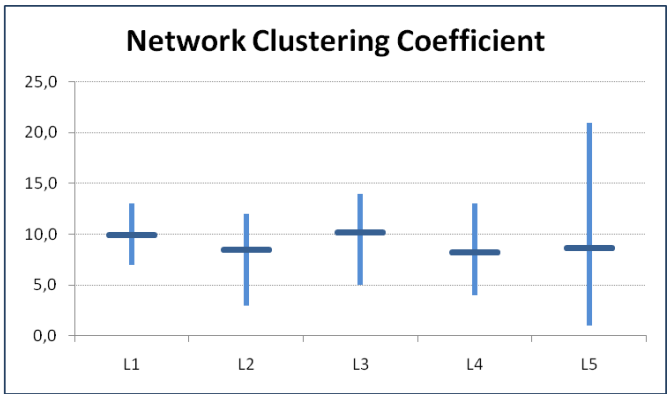


Figure 23 – ELICIT Network Clustering Coefficient

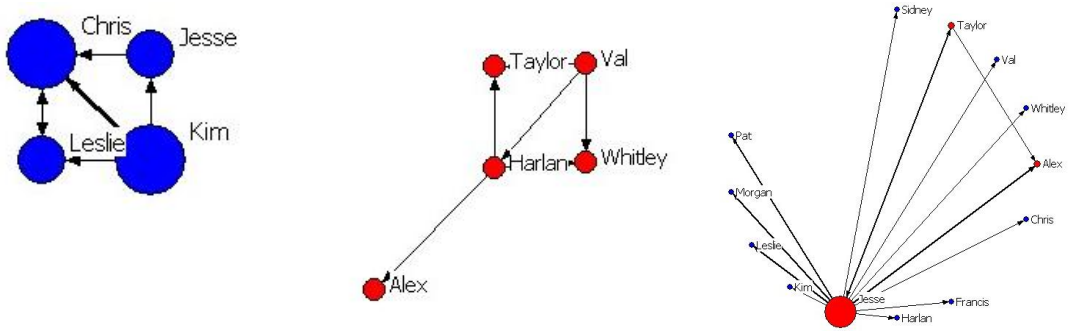
Considering that the **Network Clustering Coefficient** variable oscillates between eight and ten nodes, always connecting at least half of the network, it is clear that clustering is a natural social tendency. Change occurs naturally, with different ties forming and dissolving, due to structural mechanisms (reciprocity, transitivity) or to basic determinants of attractiveness of relational partners (influence).

Overall, it is possible to see an evolution from **High** (based on the presence of four clusters in the network) to **Low** (rigid structure prevents the search for additional node connections) and to **Very Low** (the complete absence of interaction rules leaves to chance or free will the opportunity to seek information, an activity implying a transaction cost that prompt the tendency to resort to websites' information instead of social participation), as we progress from less mature to more mature C2 approaches.

Network Connectedness

Network connectedness addresses whether and how individuals are connected to one another through the network, a useful measure to understand notions of dependency and vulnerability. A network's component consists of all nodes that can be connected to each other by at least one path, establishing thus the minimum setting for a cohesive structure. In fact, it is rare to find a network where all nodes are adjacent (directly connected) to one another.

Extracted from ELICIT runs, the following sociograms illustrate how social participation naturally discloses the human tendency to connect and bond. In L1 Conflicted, Kim's egonet accounts for the connection with three nodes, all within the subgroup as determined by ELICIT rules. In L3 Coordinated, Harlan's egonet portrays him as the intermediary connecting the pendant node cluster to Alex. In L5 Edge, Jesse's egonet indicates an active social participation in the network, reaching twelve nodes in a network of seventeen.



L1 03 Kim's Egonet **L3 03 Harlan's Egonet** **L5 03 Jesse's Egonet**

Figure 24 – Examples of Egonets in ELICIT

Usually, networks vary from strongly connected components, whether by having different paths connecting two nodes or by having short distances between the nodes or yet by being connected many times. A strong component will therefore be more stable and less subject to disruption. Network disruption may hence be obtained through the number of **cutpoints** in the network, that is, the collection of specific nodes that, if removed, would break the component into two or more pieces. The presence of many components does imply isolates or nodes that are not connected to other nodes.

In 1972, Bonacich studied connection issues and argued that being connected to connected others makes an actor central (influential) in the network. In fact, one is likely to be more influential if connected to central others, but not powerful for these nodes are not dependent on you. In this case, attention is given to the connections of one's connections, in addition to one's own connections. Also Krackhardt, in 1994, addressed the **connection measure** to define hierarchy, stating that a hierarchical structure must be connected into a single component (full embeddedness).

ELICIT collected data on average **network connectedness** is based on the reachness index and presents close figures for each of the C2 maturity levels. The measurements for the network connectedness values across the five C2 maturity levels indicate that the average figure does not compromise the integrity of available data.

Network Connectedness	
Average L1	14%
Average L2	16%
Average L3	17%
Average L4	18%
Average L5	16%

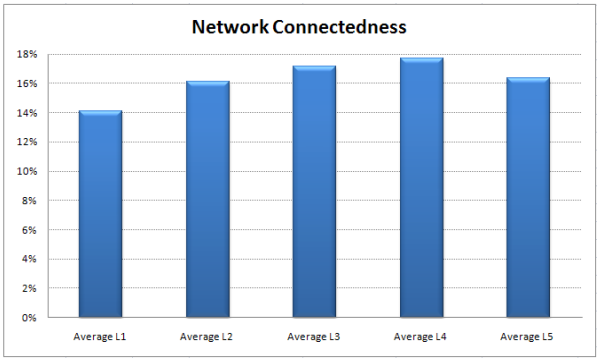


Figure 25 – ELICIT Network Connectedness

We may observe that L1 Conflicted displays the lowest average figure for **network connectedness**, since the total number of connected nodes in this network is low due to its partition into five network blocks. In L2 Deconflicted and L3 Conflicted, the hierarchical structure determines the presence of a single component with localised connections. L4 Collaborative registers the highest score in network connectedness, leveraged by the opportunity to connect to the seventeen network nodes and the existence of a cohesive team structure. L5 Edge's network connectedness average suffers from the preference to establish weak connections and to consult websites' posting. Still, because the variation between minimum and maximum network connectedness for L5 Edge is relatively large, it would be advisable to perform more ELICIT experiments.

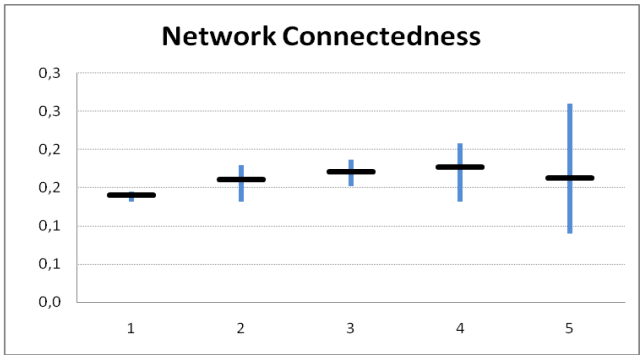


Figure 26 – ELICIT Network Connectedness

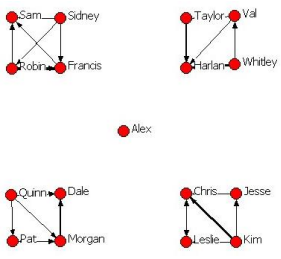
Overall, considering that the **Network Connectedness** measure varies between 14% and 19%, rates that are all equivalent to a three-node connection, we cannot see this average as a major differentiation among C2 maturity levels. Nevertheless, it is possible to observe an evolution from **Low** (minimum node reach) to **Medium** (limited node reach) and to **High** (a full node reach that is combined with the effects of connection costs and independent information-seeking behaviour), as we progress from less mature to more mature C2 approaches.

Network Structural Cohesion

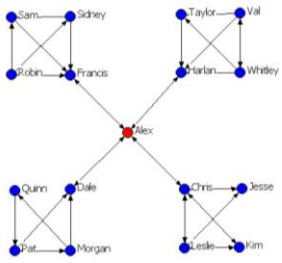
Based on node connectedness, the network's **structural cohesion** is defined as the minimum number of actors who, if removed from a group, would disconnect the group, in other words, the number of nodes pertaining to smallest key core of the network (a key core is the set of nodes that are more closely connected). As an emergent property of patterns of interaction, structural cohesion rests upon embeddedness and *reachability* (Markovsky and Lawler, 1994), illustrates node stability and institutionalisation and hints on trust and confidence issues. In fact, if the frequency of bonding suggests hierarchical nests (asymmetric connections), the predominance of reciprocated ties indicates a balanced network where social capital is unified with trust.

In 1992, Ronald Burt focused on node embeddedness and created a new concept, **structural holes**, designating the lack of connection between an ego's alters, nodes that incurred in serious danger of becoming either isolated or connected to a different network. On one hand, this new approach reinforced the notion of betweeness (the powerful intermediary condition controlling the flow of information), while it highlighted the idea of brokerage, a form of social capital centred in the ability to reduce dependency effects, extending own neighbourhood and attracting new sources of information.

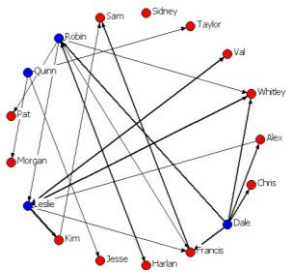
Extracted from ELICIT runs, the following sociograms identify the network's **blocks and cutpoints**, being these the specific nodes that, if removed, cause the dissolution of the network as is (these nodes only have one degree relationships). In L1 Conflicted, there are no blocks and cutpoints, for the network is divided into specific small blocks that have to bond to exist. In L3 Coordinated, it is possible to see Alex role as the cutpoint, for this node's removal will dissolve the network. In L5 Edge, it is possible to identify four cutpoints that establish precious ties with pendant nodes, in danger of becoming isolates.



L1 03 Blocks and Cutpoints



L3 01 Blocks and Cutpoints



L5 02 Blocks and Cutpoints

Figure 27 – Blocks and Cutpoints in ELICIT

ELICIT collected data on the average of the smallest key core (pendant nodes or structural holes) is:

Network Structural Cohesion	
Average L1	3,00
Average L2	4,50
Average L3	2,50
Average L4	2,75
Average L5	7,00

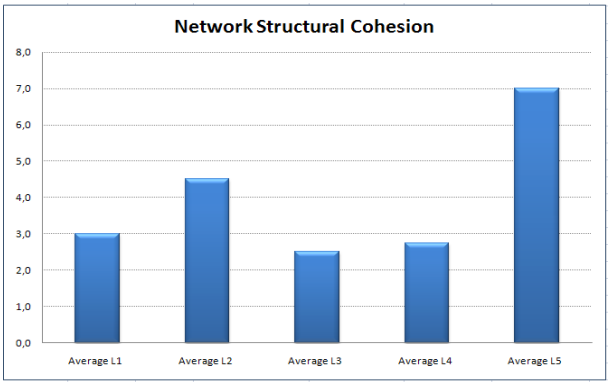


Figure 28 – ELICIT Network Structural Cohesion

We may observe that L1 Conflicted exhibits a poor result on **structural cohesion**, for the whole network would collapse if only three nodes were removed. In L2 Deconflicted, the results indicate the presence of a stronger network, with ties of dependence dictated by the organisation's structure establishing the smallest key core with four nodes. That value decreases to two and a half nodes in L3 Coordinated and L4 Collaborative due to the partition of the network in small hierarchical clusters. This embeddedness does not apply to L5 Edge, with a cutpoint of seven nodes, determining that almost half of the network would have to lose its connections before there would be two components.

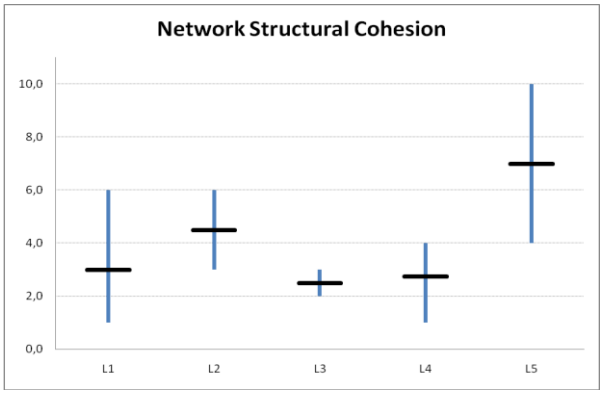


Figure 29 – ELICIT Network Structural Cohesion

Still, the difference between the minimum and maximum values for **network structural cohesion** in almost every C2 maturity level implies that further investigation should be conducted on this matter to reinforce available data.

Overall, we may see that the **Network Structural Cohesion** evolves from **Low** (minimum network cohesion of structurally cohesive independent blocks) to **Very Low** (small network cohesion of asymmetric connections) and to **High** (high network cohesion with multiple independent bonding paths hold the entire network together), as we progress from less mature to more mature C2 approaches.

Evolving From Less Mature to More Mature C2 Approaches

The NATO NEC Command and Control Maturity Model (N2C2M2) states that more mature collective C2 approaches (full distribution of decision rights across the organisation, unlimited sharing interaction and wide information dissemination) attain higher levels of shared awareness and understanding that, in turn, result in increased endeavour effectiveness, efficiency and agility.

Matching the N2C2M2 model to ELICIT features has enabled the application of a Social Network Analysis (SNA) to assess the behaviour of the seventeen involved players when acting in accordance to each crafted collective C2 approach. To capture the essence of the N2C2M2 principles and represent it with the assistance of the SNA theory, a number of variables were selected. Thus, node centrality, node embeddedness, network activity, network path length, network diameter, network inclusiveness, network clustering coefficient, network connectedness and network structural cohesion are the SNA variables that allow us to establish an overall framework for each of the collective C2 approach.

Hence, the L1 Conflicted collective C2 approach presents a network where isolated blocks hamper node centrality and embeddedness, preventing the emergence of key nodes in the network, whether through social participation, communication control or interaction efficiency. The nodes' agency is not able to develop and leads to the overall network's low level of activity, specifically of sharing behaviour, which usually follows geodesic or direct path lengths. Despite the small network diameter,

inclusiveness is again reduced to the presence of a single isolated node and of four isolated blocks, which promote significantly the network's clustering coefficient, that is, the association of a small group of nodes. Still, the reduced index of connectedness among those groups is then translated to a poor network structural cohesion. As a consequence of these social characteristics, the L1 Conflicted network presents no shared information in the network (no interaction patterns across entities) with a constrained distribution of information occurring within the small group of nodes (teams) and accounting for a reach that never surpassed 14% of the network. As a result, despite some teams having attained the solution for their specific problem space, overall organisation success, with all teams finding the correct solution, is not achieved.

The L2 Deconflicted collective C2 approach presents a network of four teams and a Deconflictor whose role is to pass information forward from and to every team, enabling and controlling information sharing and flow. The network is therefore characterised by limited peer-to-peer interactions and a stove-piped chain of command, making specific nodes in the network very central or relevant for the ongoing communication and contributing to the overall node embeddedness in the organisational structure (not strong in terms of density but reinforced in terms of link strength and flows). The Deconflictor does contribute to the increased level of network activity, across higher path lengths, built upon a larger network (comparing to L1 Conflicted) and hierarchical ruling. In fact, the network's diameter enters the fourth order zone (three intermediaries), reaching an average of 16% of the network and rejecting all possibilities of isolation, while contributing to the reduction of the network clustering coefficient. The network's structural cohesion benefits therefore from these enlarged dependency links that generate a limited information sharing pattern and result in improved effectiveness, despite overall organisation success did not occur.

The traditional hierarchic formation is depicted in L3 Coordinated collective C2 approach, with the organisation depending on the Coordinator to perform the role of having to gather, process and understand all information available so as to make the correct identifications. This network displays high levels of node centrality and embeddedness (influenced by the flow and the strength of links established on account of node positioning and role setting) but decreased activity, for social dynamics and participation is focused in feeding the Coordinator with information, using the formal network configuration. As a consequence, the network's average path length diminishes to accommodate a three-tier hierarchical relationship that isolates no node and encourages a clustering behaviour, exhibiting a medium structural cohesion index. Having the organisation's success depend on the Coordinator determines a single point of failure that, three out of four times, has proven to be unwise for the network's effectiveness was severely compromised. In the end, it is mainly the quality of the Coordinator that determines the quality of the overall organisation.

The L4 Collaborative collective C2 approach has demonstrated to be a solid and resourceful network configuration, whose performance is facilitated when organisational success depends of the Facilitator or the four Team Leaders finding the correct solution. Still, as expected, the network displays reduced centrality and embeddedness levels and higher social participation activity, prompted by the increased relevance of each node's agency. The dependence on teams for a localised decision-making activity is reflected by the establishment of lower path lengths (the network's diameter is of a third order zone) and the tendency to prevent vulnerability by relying on a limited number of sources. Therefore, isolated undertakings are possible, affecting network inclusiveness (the highest score of all five collective C2 approach due to higher number of isolates), clustering (the lowest score of all five collective C2 approach due to an independency trend), connectedness (the highest score of all five collective C2 approach reaching 18% of the network) and structural cohesion (one of the lowest scores of all collective C2 approach for the network had less than three pendant nodes). In the end, the freedom to pursue information does not imply the problem of handling with eventual information overload, for it is balanced with the dismissal of responsibility in the decision-making process. As a result, and considering the benevolent performance assessment, it is possible to observe the best effectiveness level of all five collective C2 approach organisations.

Finally, the L5 Edge collective C2 approach explored the opportunity to have all information accessible and reachable, to entail on unlimited sharing as required and to promote the dynamic emergence of decision rights, empowering a resilient, decentralised and networked organisation. By comparison with the previous collective C2 approach, the L5 Edge organisation regains some centrality, in the sense that it is possible to note individual prominence: key or central nodes within the network emerge due to their influential communication activity, or bridging ability to reach out to all nodes in the network or yet circumventing skill to avoid dependency on a particular source of information. These features are reinforced by the reduction of all embeddedness variables (link density, strength and flow) in the face of the recognition of weak ties' strength in the pursuit of a rewarding network configuration. And this pursuit is extremely well represented in the network's activity score, the highest of

all five collective C2 approaches and a sign that massive social participation forwards empowerment and leads to increased satisfaction levels. As a consequence, the network establishes a larger neighbourhood and a wider diameter, and even comprises the lowest number of path length 3 connections and a reduced occurrence of isolationist behaviours, up to the moment where the transaction costs advise the resource to website pulling and posting. In fact, L5 Edge collective C2 approach presents the highest risks on interactions engagement: subjects have to balance the wonder of full network reach with the unawaress of potential beneficial outcomes, the lack of assurance on reciprocity and the compromise of their status and prominence. To downplay these negative effects on social capital, it is the human nature to flock in small groups and, based on the stability provided by clustering, reach out to novel information through multiple, redundant and independent paths that bond the network together and determine that almost half of its nodes would have to lose their connections before the whole network collapsed. Indeed, this collective C2 approach reveals the highest structural cohesion of all five collective C2 approaches, reinforced by the highest levels of shared awareness and understanding. Still, the limitations imposed on the effectiveness assessment for this particular organisation (the organisation's success is determined by the mode of answers provided) has taken a negative toll on the overall performance, although the extremely promising time-efficiency levels.

5 KNOWING THE NETWORK, KNITTING THE NETWORK

Organisations are built on complex interactions. But how does success emerge from the complex collaboration connections within organisations?

SNA may prove the first statement but the improvement of connectivity requires more than knowing the network, it requires knitting the network.

Social network analysis enables the understanding of the embedded network system, not forsaking the answer to particularly relevant enigmas for the emergence of an efficient and effective organisation: are the key connections in place, which are the influential actors involved, are ideas shared and acted upon?

A network map is an excellent tool for visually tracking your ties and design strategies to create new connections. When local interactions lead to global patterns, scientists call it emergence (Krebs and Holley), the goal is to understand and catalyze interactions.

Successful organisations run on common goals or governance. Successful organisations view the diversity of interactions as the requirement to maximize innovation. Successful organisations are robust networks in which several paths between any two nodes guarantee uninterrupted information flow and knowledge exchange. Successful organisations know that some individuals are more prominent than others, for they act as hubs (distribution and diffusion of information), as brokers (liaisons to novel information and knowledge) or as boundary spanners (bridging relevant groups).

Empowered with the knowledge of the networked organisation, it is vital to actively manage the network, that is, to knit the network, so that a more robust, resilient, responsive, flexible, innovative, adaptive and sustainable network structure is built and a creative organisation emerges.

And social network analysis reveals the progress of network knitting the organisation, through the process of relationship building (access to information and innovation) and of collaboration facilitation. The culture of collaboration increases the organisation's scale, impact and reach, creating a state of emergence, where the outcome — the creative organisation — is more than the sum of the many collaborations, is a new dynamic for work flow, information exchange and knowledge sharing.

The creative organisation (Manso, 2008) presents thus a network core model featuring the key organisation members, while the periphery of the network embraces the new elements of the organisation that ambition to reach its core, the bridge nodes that liaise to diversified communities and external unique resources that represent an added-value to the organisation whenever it is required. In the core/periphery network structure, the porous periphery functions are the organisation's radar, reaching out to new ideas, information and knowledge, whereas the strong core allows the organisation to act on those ideas, information and knowledge.

Throughout this network knitting process, social network analysis guides the path ahead, revealing what we should know and uncovering what we ought to know. SNA enables to gather the necessary skills and resources to build a more agile organisation (Alberts and Hayes, 2003), maximized for collaboration, learning and implementation.

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KNOW THE NETWORK, KNIT THE NETWORK:

APPLYING SNA TO N2C2 MATURITY MODEL EXPERIMENTS

by Bárbara Manso and Marco Manso

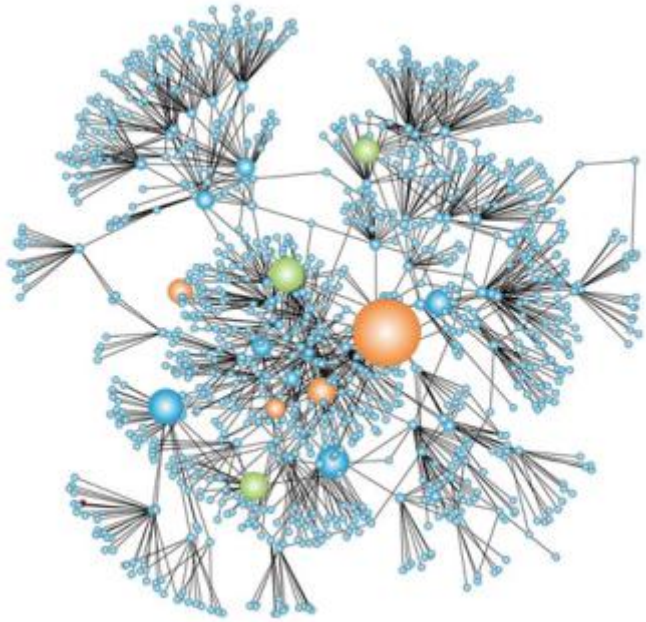
15th ICCRTS
June 23rd 2010

EDI SOFT

Table of Contents

The Value of SNA

- **Social Network Analysis (SNA)** is a scientific methodology that assists in the explanation of networking and personal interactions.

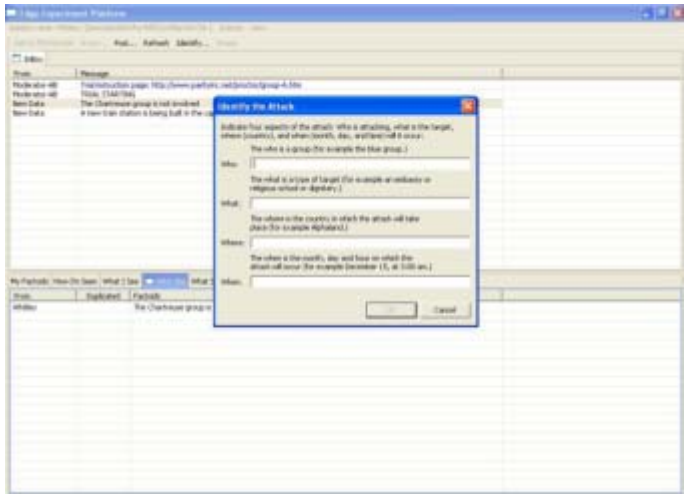


- **SNA** focuses on **individuals or nodes** and on **degrees or links**

- **SNA** enables to determine how the **network's structure, location and connection properties affect organisational performance and effectiveness**.

Mapping SNA to ELICIT

- **ELICIT** is an experimentation platform that instruments the actions of a group of seventeen participants engaged in a situational awareness problem, with the goal to identify the who, what, when and where of a pending attack.



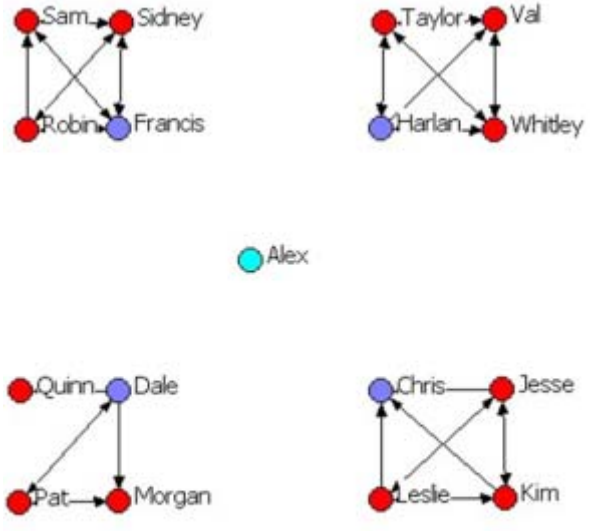
- **ELICIT participants** build situational awareness by gathering and analyzing factoids and **interacting with one another** through **factoids' sharing** directly with each other or **factoids' posting** to websites.

SNA Findings in the N2C2M2 ELICIT Experiments

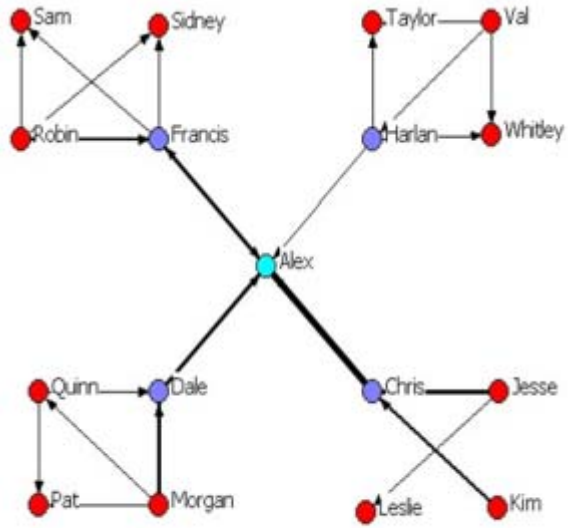
SNA Variable	*SNA Variable Description*
Node Centrality	Compound variable, measured by: - Node Degree – number of nodes to which a node is directly related to; - Closeness – degree to which a node is close to all other nodes; - Betweeness – frequency by which the node is located between pairs of other nodes.
Node Embeddedness	Node Embeddedness – a compound variable, measured by: - Link Density – the relation between the node's links and the total number of links; - Link Strength – number of times a link has been used; - Link Flow – number of in-degrees and out-degrees of a node.
Network Activity	Number of times each link has been used
Network Mode Path Length	Mode of all nodes' path lengths
Network Diameter	Maximum path within the network
Network Inclusiveness	Relation between the number of isolated nodes and the total number of nodes
Network Clustering Coefficient	Likelihood that two associates of a node are associates themselves
Network Connectedness	Capability of each node to reach all other nodes in the network
Network Structural Cohesion	Minimum number of nodes that, if removed, causes the network to collapse

SNA Findings in the N2C2M2 ELICIT Experiments

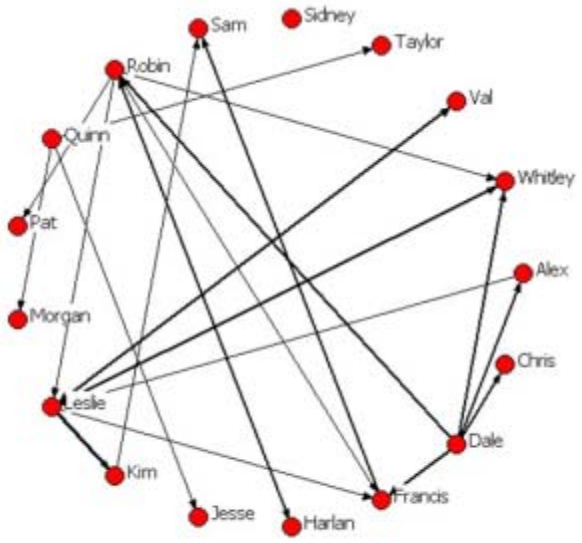
Node Centrality



L1 01 Sociogram



L3 03 Sociogram

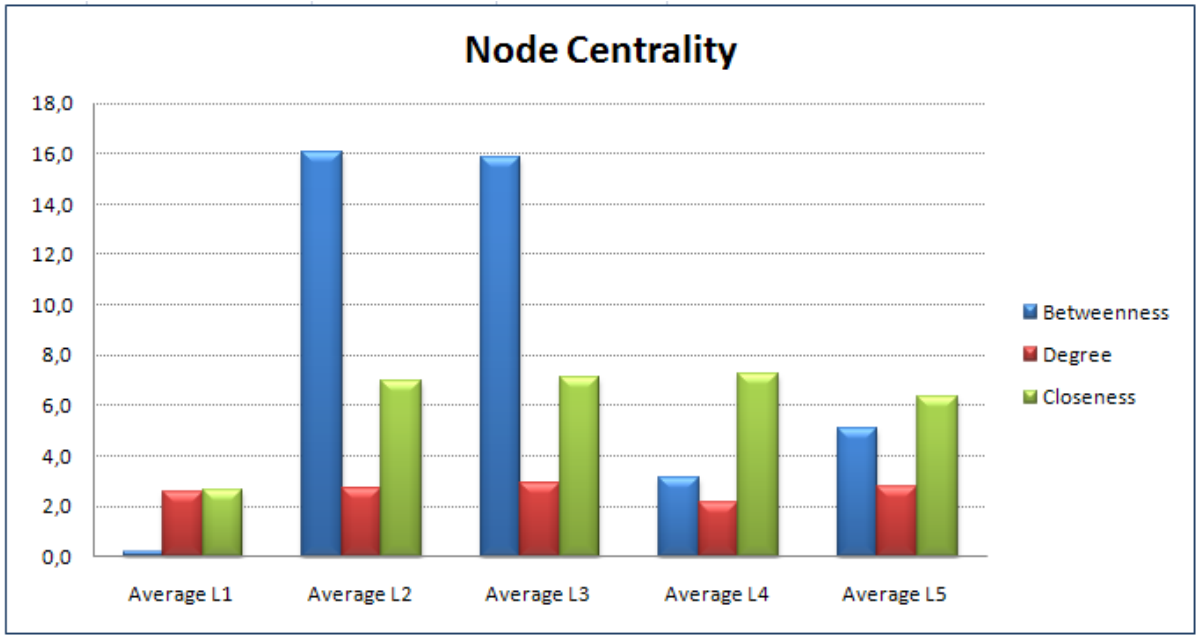


L5 02 Sociogram

SNA Findings in the N2C2M2 ELICIT Experiments

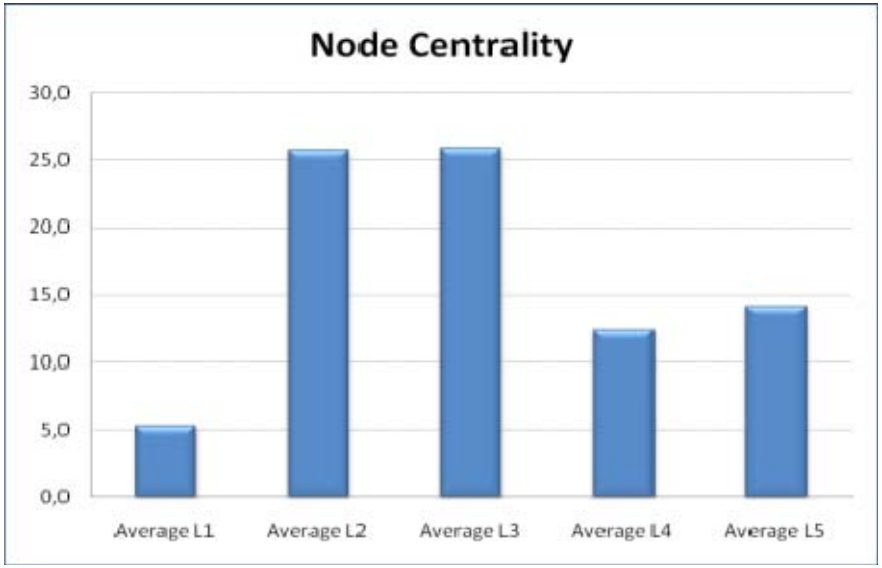
Node Centrality

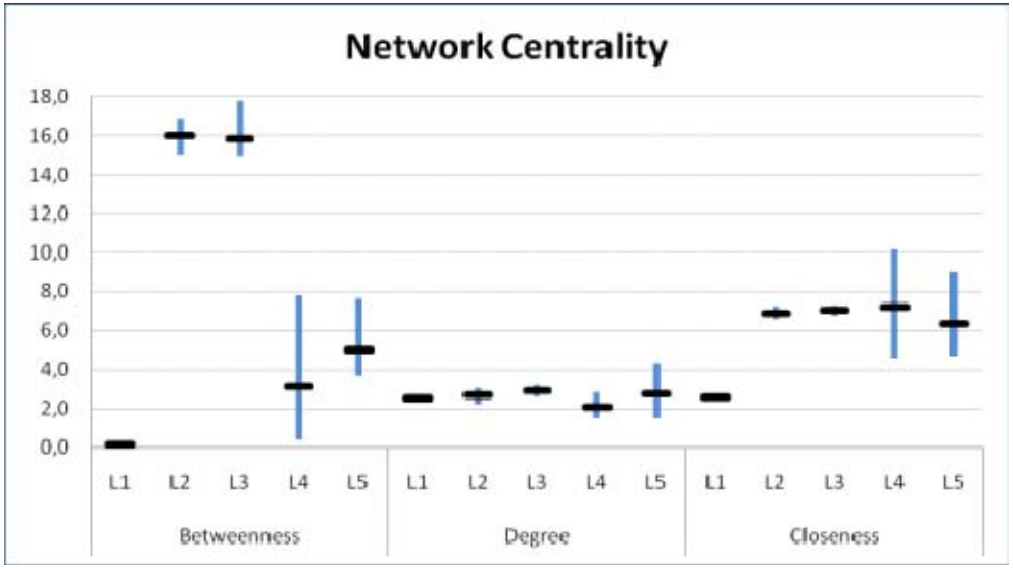
Node Centrality			
	Betweenness	Degree	Closeness
Average L1	0,196	2,529	2,627
Average L2	16,059	2,735	6,946
Average L3	15,857	2,912	7,081
Average L4	3,154	2,132	7,223
Average L5	5,059	2,745	6,363



SNA Findings in the N2C2M2 ELICIT Experiments

Node Centrality



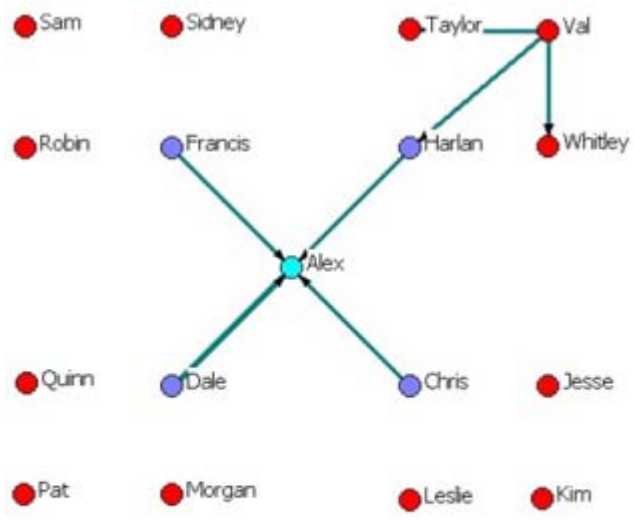


SNA Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
Node Centrality	From VERY LOW (isolated node) to HIGH (central node sets) and to MEDIUM (decentralised network)

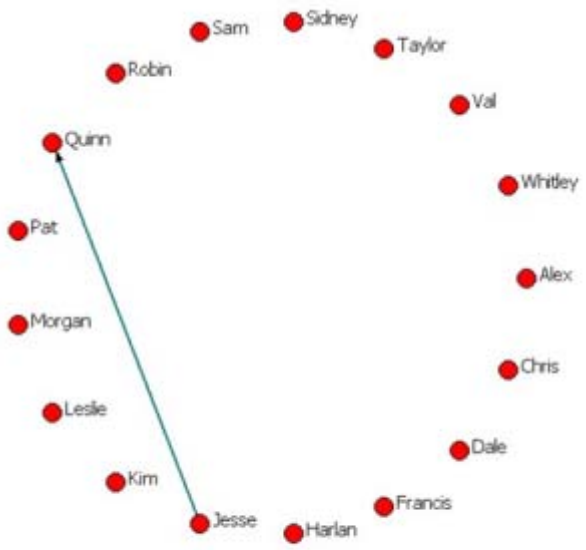
SNA Findings in the N2C2M2 ELICIT Experiments

Node Embeddedness

L1 02 More than 5
Link Strength Connection



L3 01 More than 5
Link Strength Connection

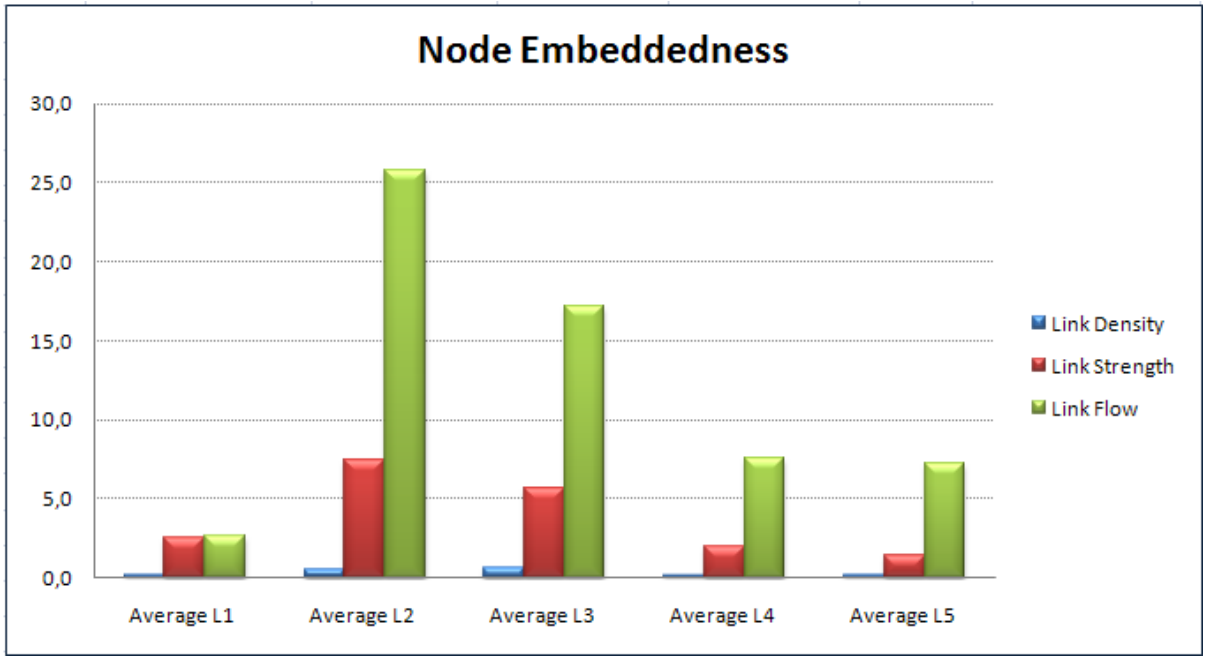


L5 03 More than 5
Link Strength Connection

SNA Findings in the N2C2M2 ELICIT Experiments

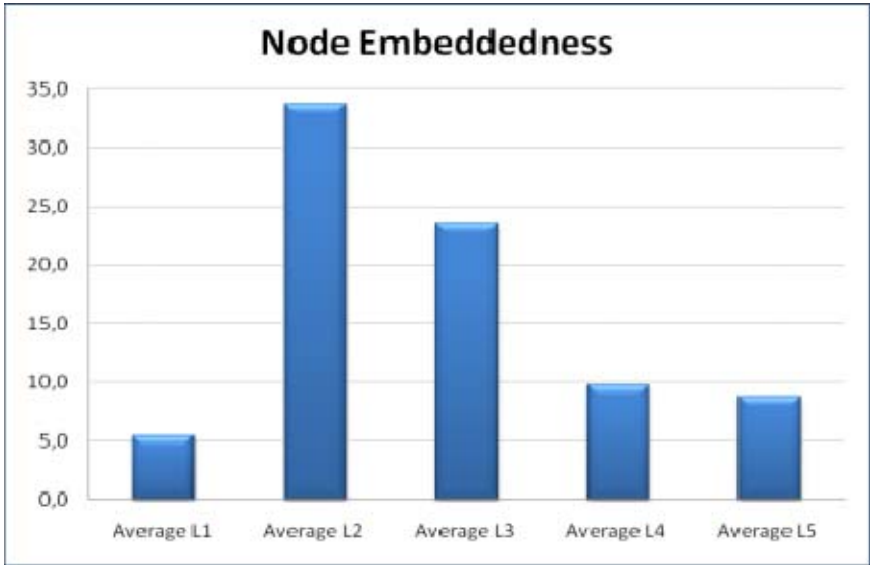
Node Embeddedness

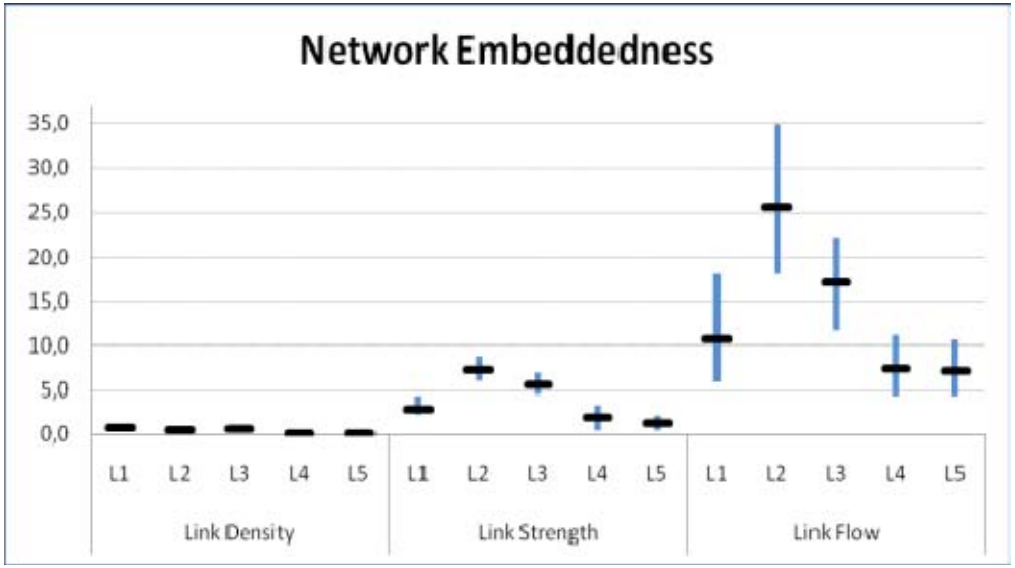
Node Embeddedness			
	Link Density	Link Strength	Link Flow
Average L1	0,196	2,529	2,627
Average L2	0,549	7,397	25,750
Average L3	0,659	5,647	17,176
Average L4	0,143	2,029	7,529
Average L5	0,208	1,392	7,176



SNA Findings in the N2C2M2 ELICIT Experiments

Node Embeddedness

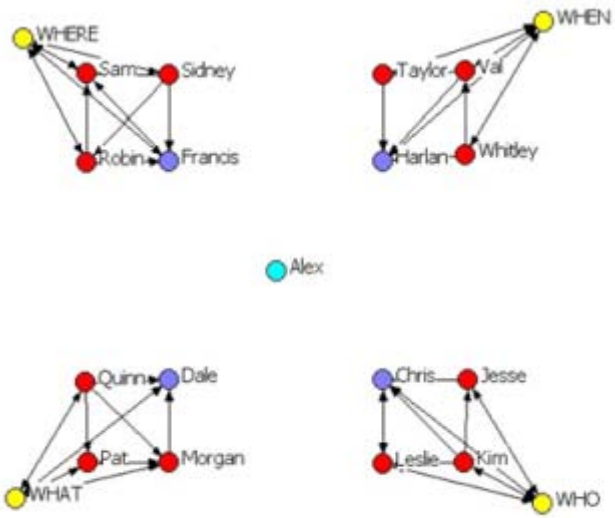




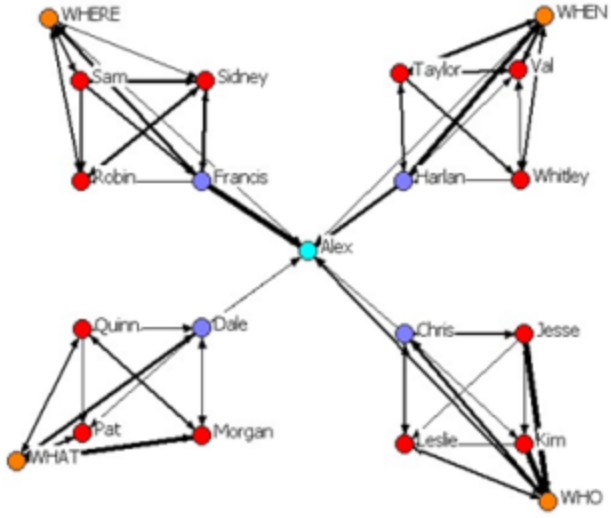
SNA Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
Node Embeddedness	From LOW (low density) to HIGH (high density) and to MEDIUM (distributed density)

SNA Findings in the N2C2M2 ELICIT Experiments

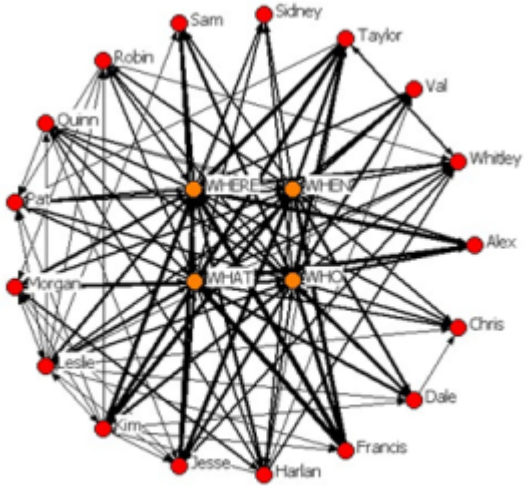
Network Activity



L1 03 Sociogram with websites



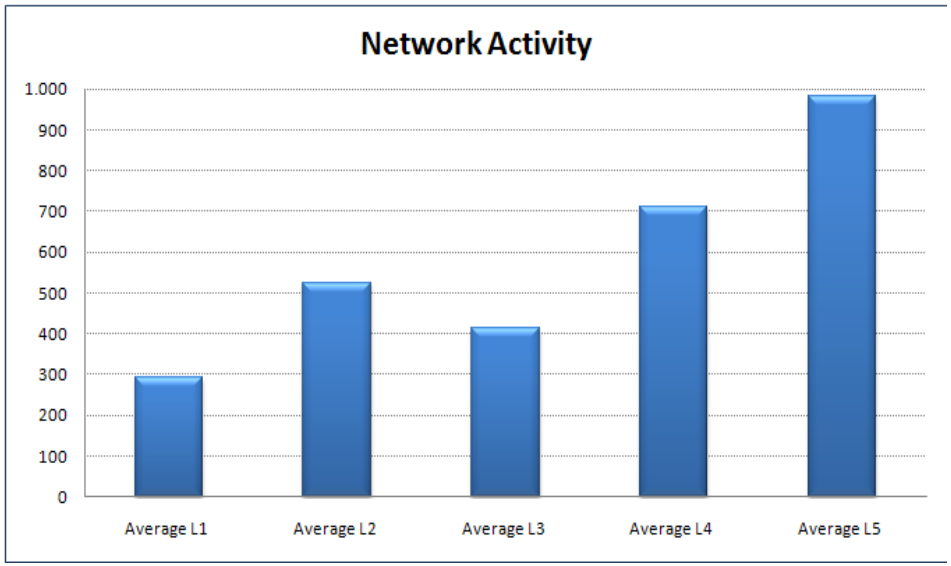
L3 04 Sociogram with websites

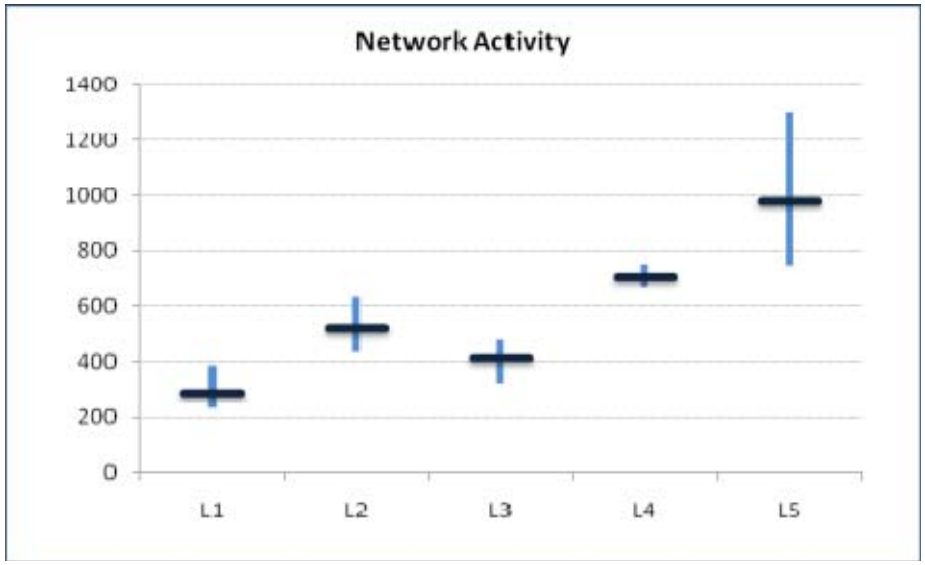


L5 03 Sociogram with websites

SNA Findings in the N2C2M2 ELICIT Experiments

Network Activity

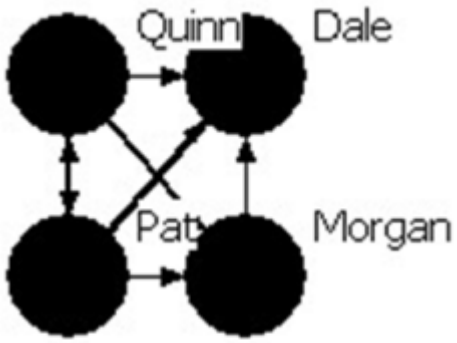




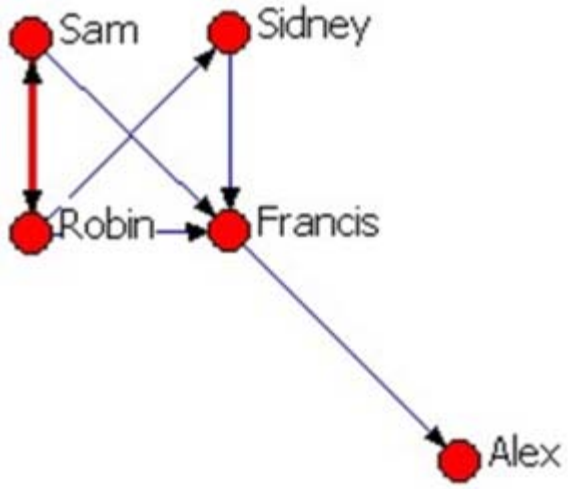
SNA Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
Network Activity	From LOW (minimal degrees) to MEDIUM (limited degrees) and to HIGH (multiple degrees)

SNA Findings in the N2C2M2 ELICIT Experiments

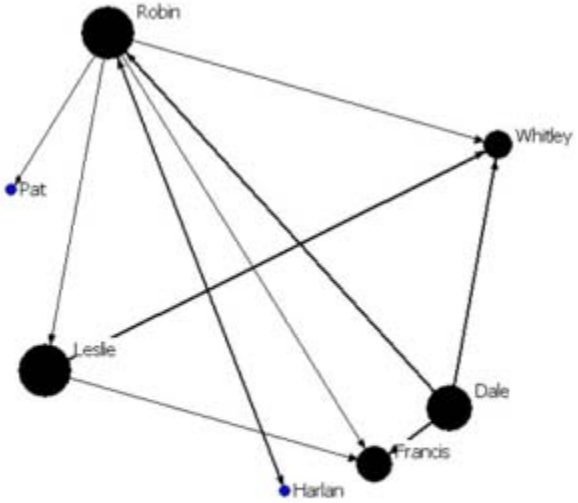
Network Path Length



L1 02 Dale's Egonet



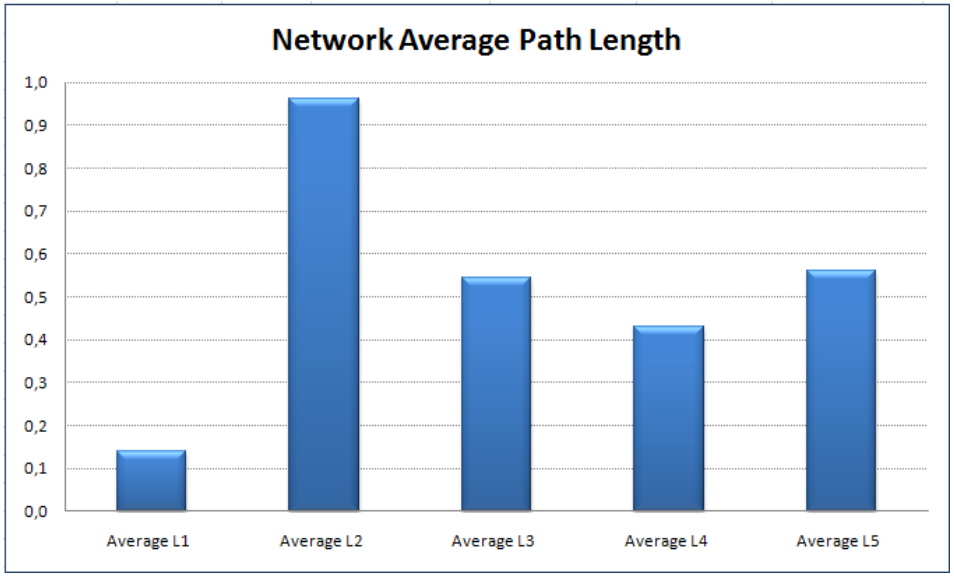
L3 02 Francis' Egonet

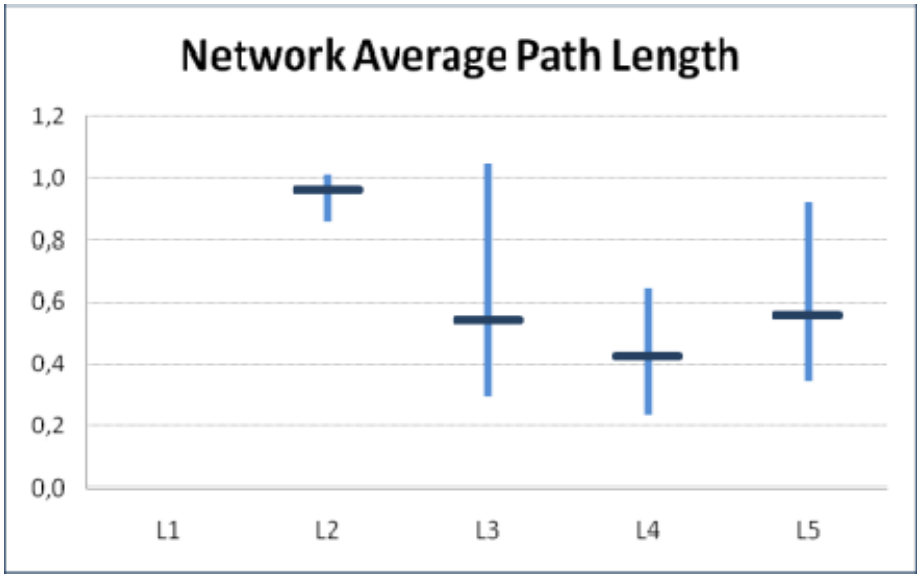


L5 02 Robin's Egonet

SNA Findings in the N2C2M2 ELICIT Experiments

Network Path Length

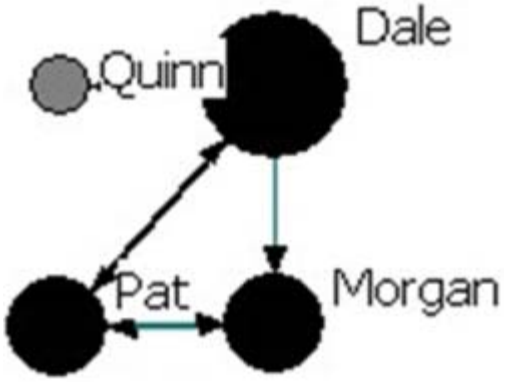




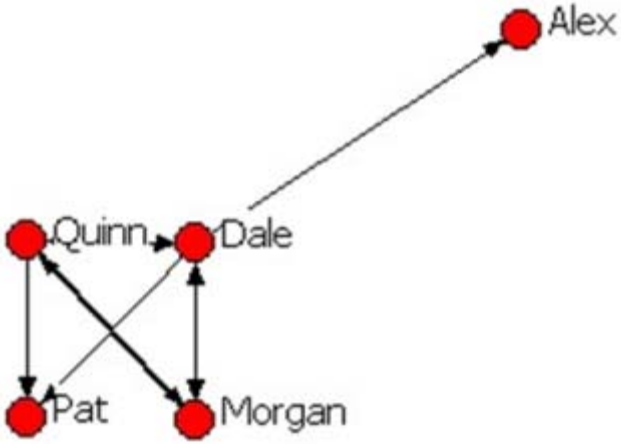
SNA Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
Network Mode Path Length	From HIGH (first order zone) to LOW (hierarchical rules) and to LOW (geodesics)

SNA Findings in the N2C2M2 ELICIT Experiments

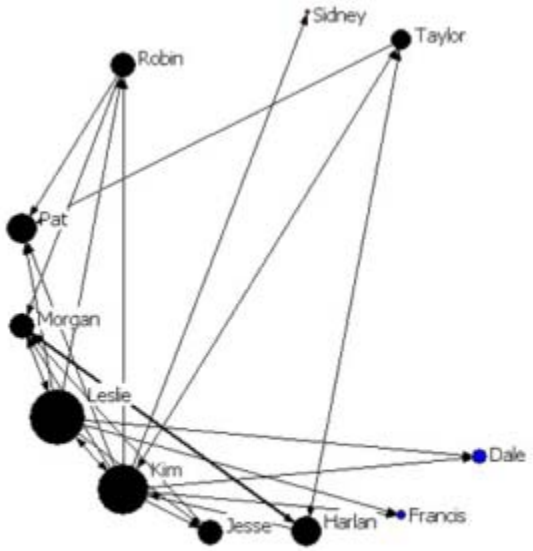
Network Diameter



L1 01 Dale's Egonet



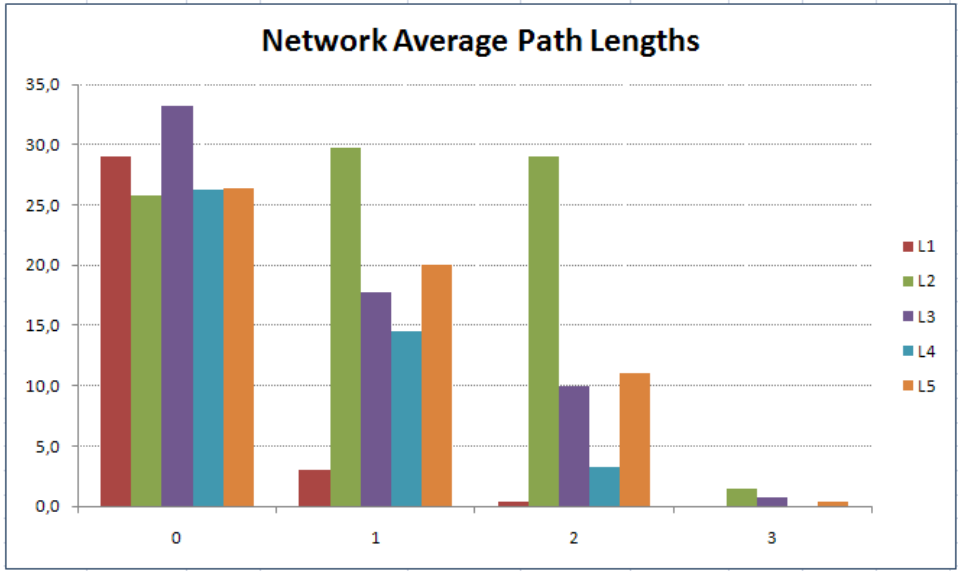
L3 04 Dale's Egonet

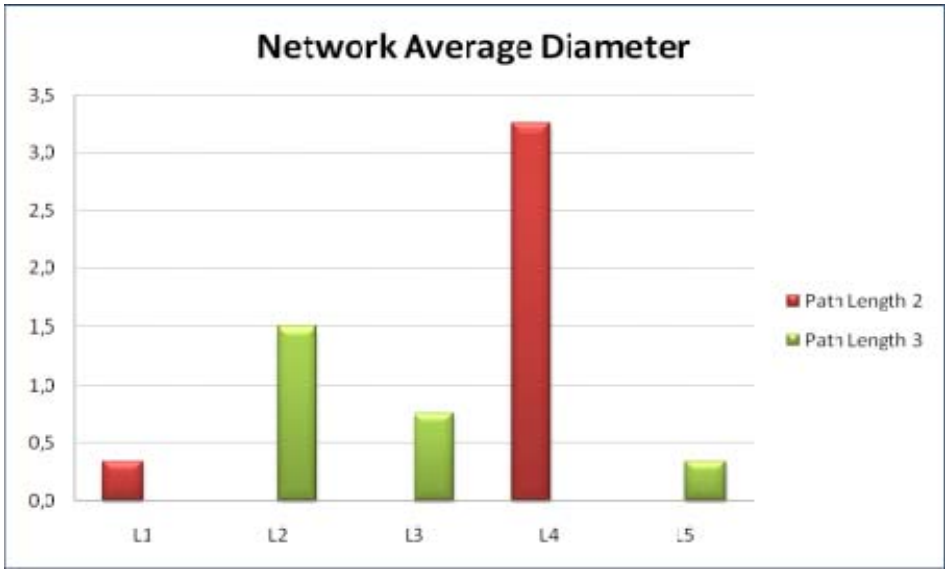


L5 01 Kim's Egonet

SNA Findings in the N2C2M2 ELICIT Experiments

Network Diameter

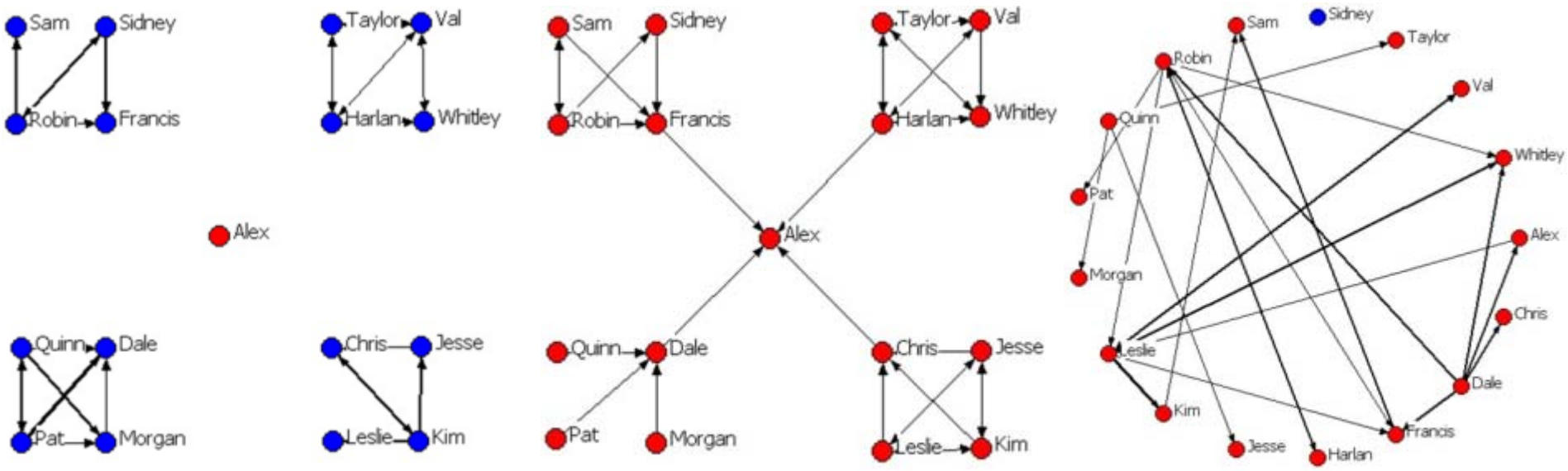




SNA Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
Network Diameter	From LOW (adjacency) to MEDIUM (hierarchical setting) and to LOW (wider neighbourhood of geodesics)

SNA Findings in the N2C2M2 ELICIT Experiments

Network Inclusiveness



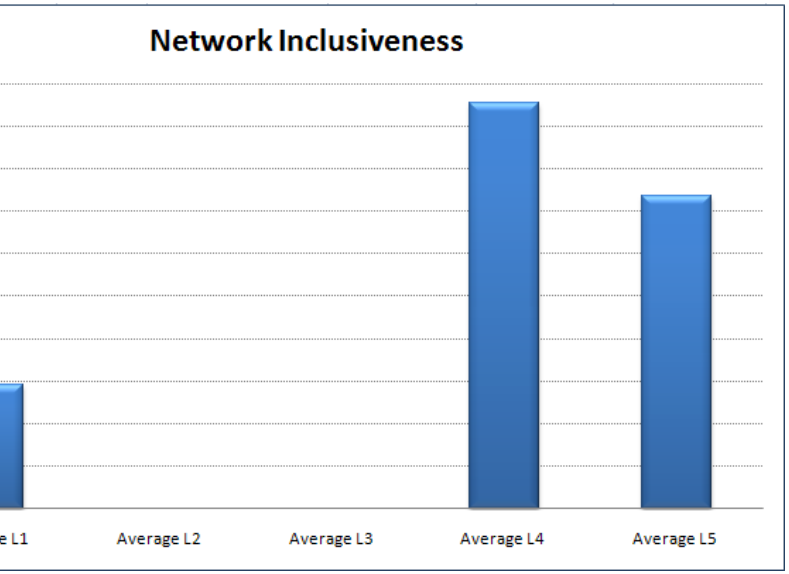
L1 02 Isolates

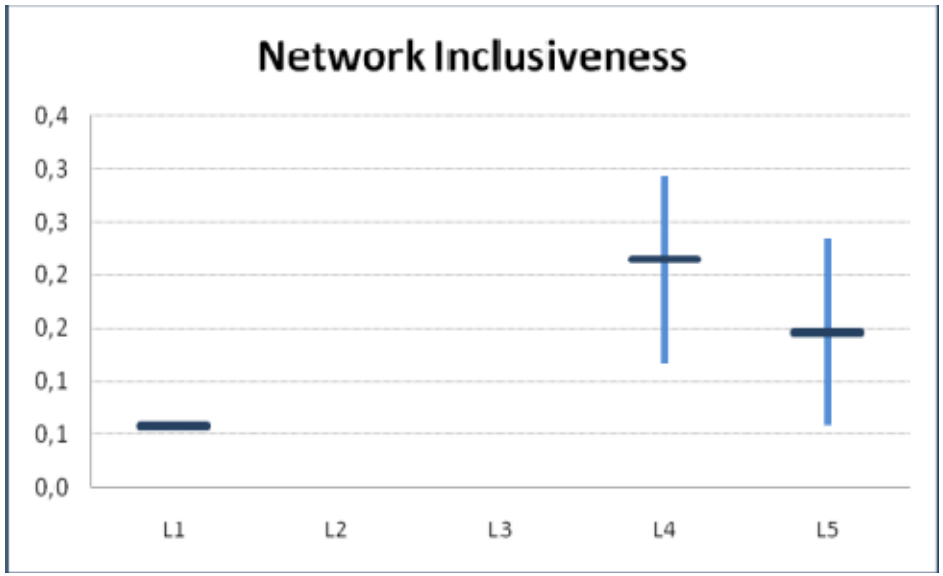
L3 02 Component

L5 02 Isolates

SNA Findings in the N2C2M2 ELICIT Experiments

Network Inclusiveness

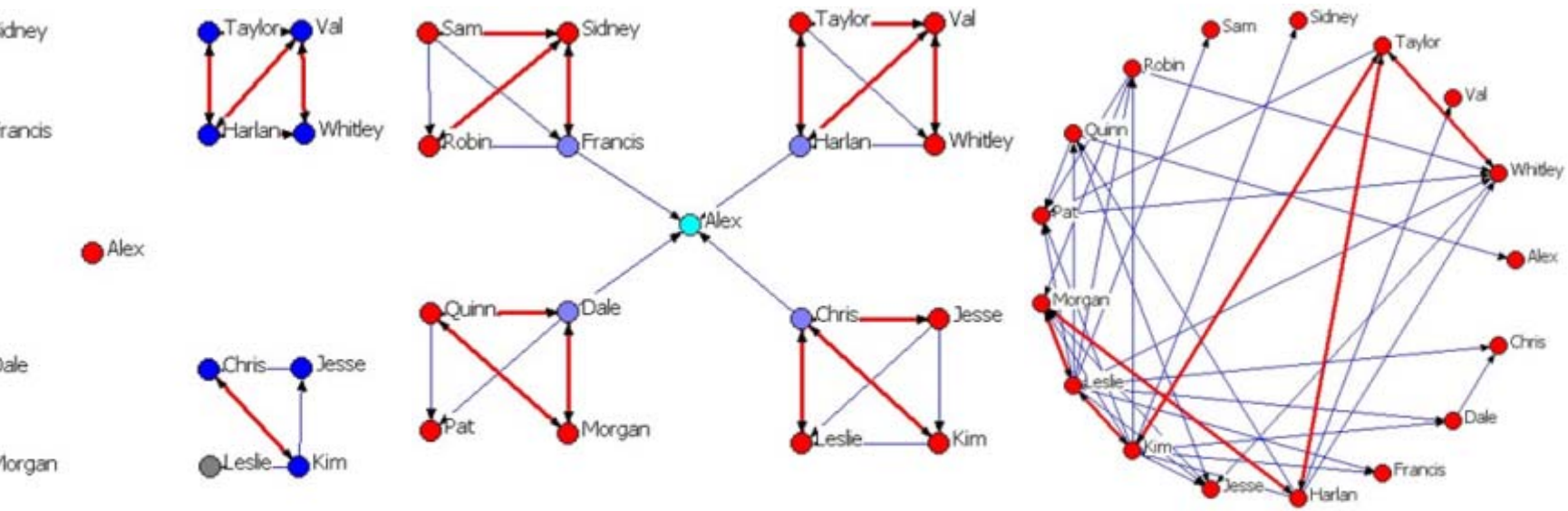




A Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
clusiveness	From LOW (one isolate) to NOT APPLICABLE (no isolates) and to MEDIUM (isolated node behaviour)

SNA Findings in the N2C2M2 ELICIT Experiments

Network Clustering Coefficient



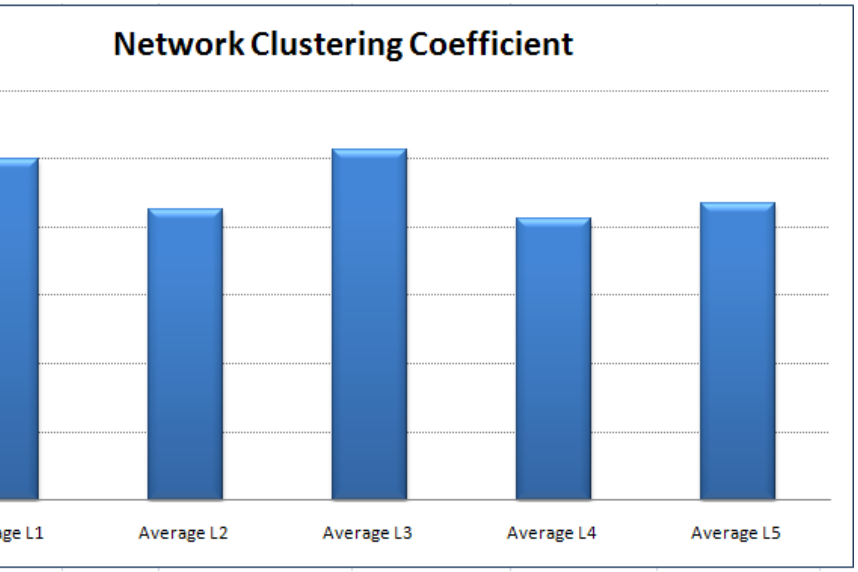
2 Reciprocal Ties

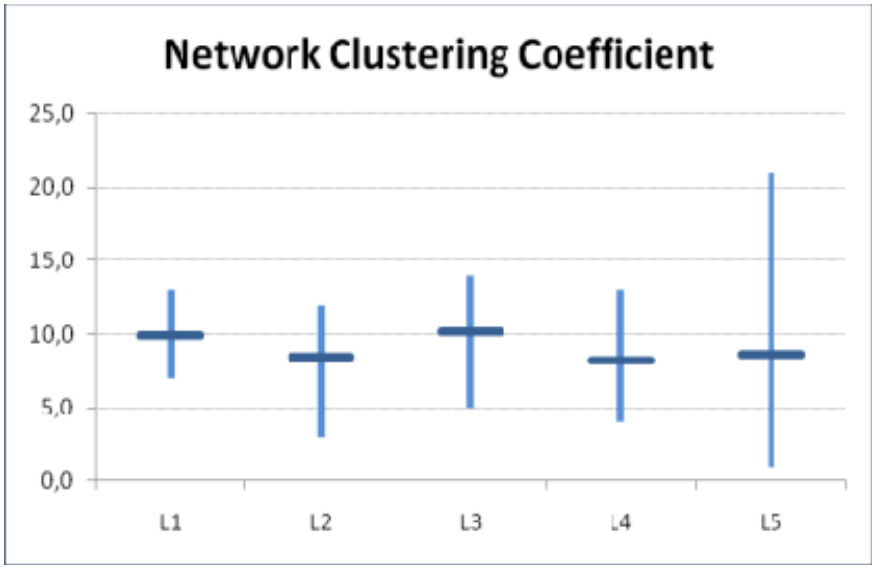
L3 04 Reciprocal Ties

L5 01 Reciprocal Ties

SNA Findings in the N2C2M2 ELICIT Experiments

Network Clustering Coefficient

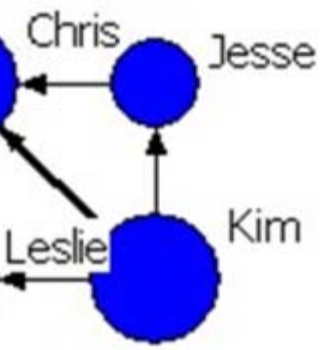




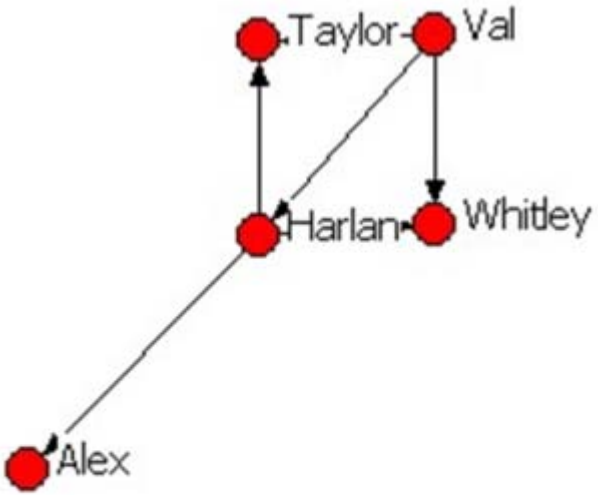
A Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
ustering Coefficient	From HIGH (small node sets) to LOW (rigid node association) and to VERY LOW (free node association)

SNA Findings in the N2C2M2 ELICIT Experiments

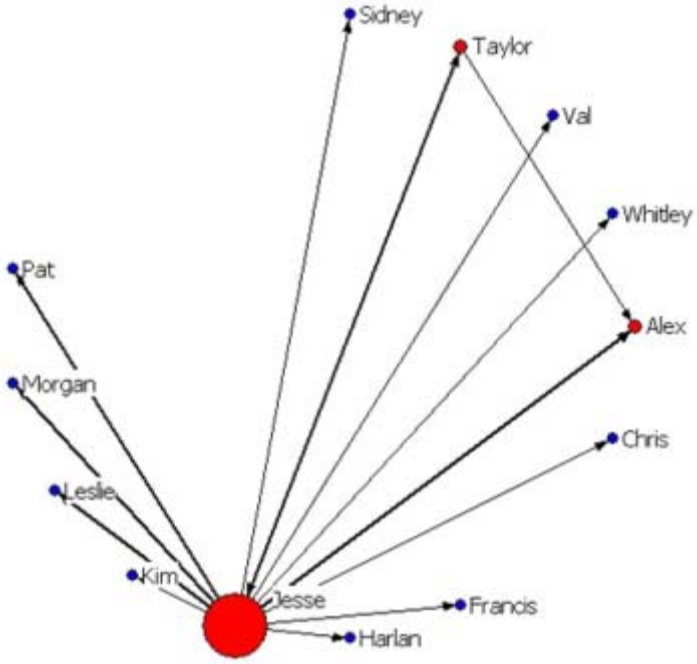
Network Connectedness



03 Kim's Egonet



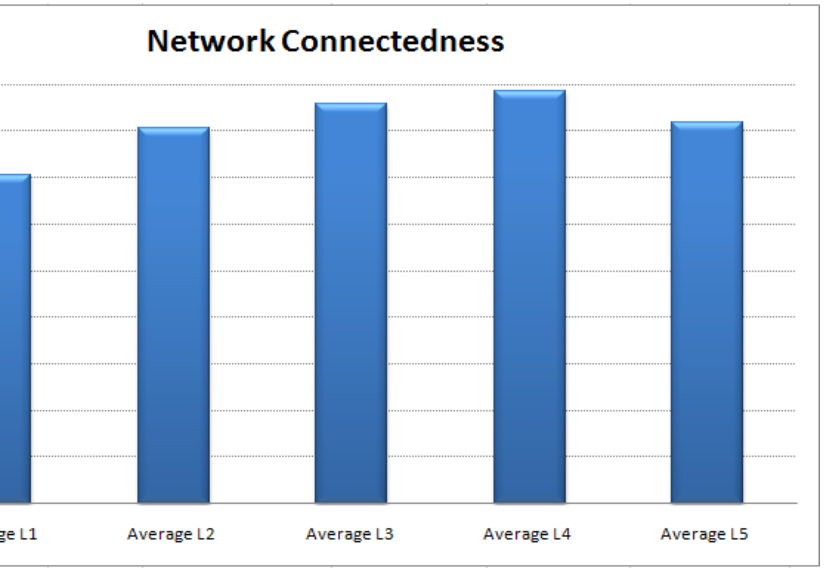
L3 03 Harlan's Egonet

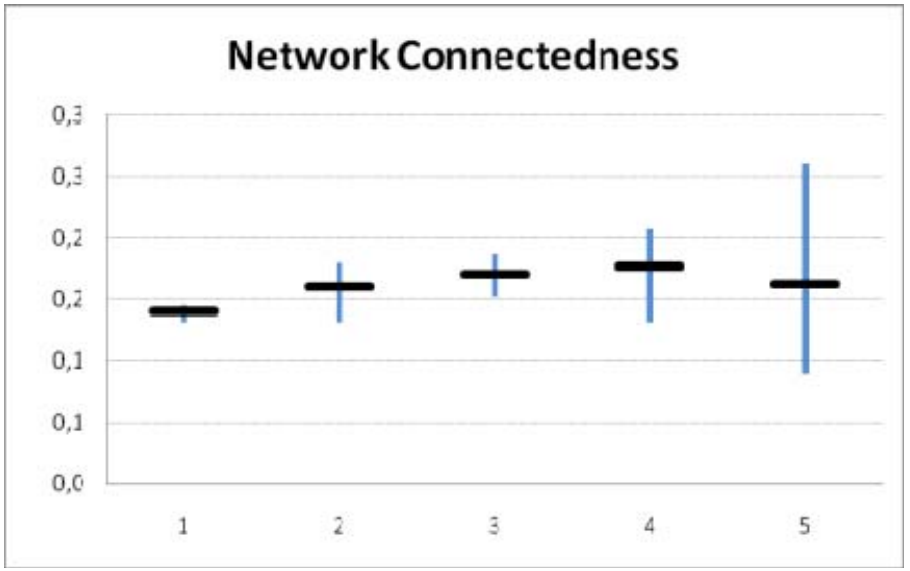


L5 03 Jesse's Egonet

SNA Findings in the N2C2M2 ELICIT Experiments

Network Connectedness

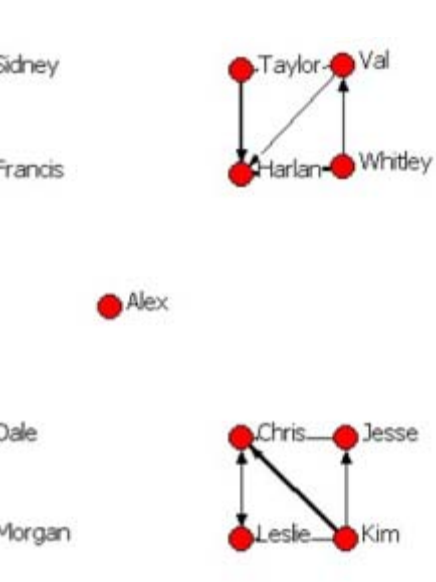




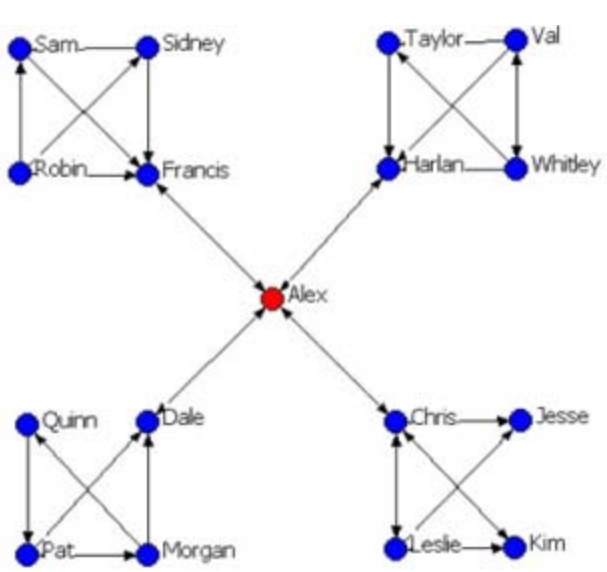
A Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
nnectedness	From LOW (minimum node reach) to MEDIUM (limited node reach) and to HIGH (full node reach)

SNA Findings in the N2C2M2 ELICIT Experiments

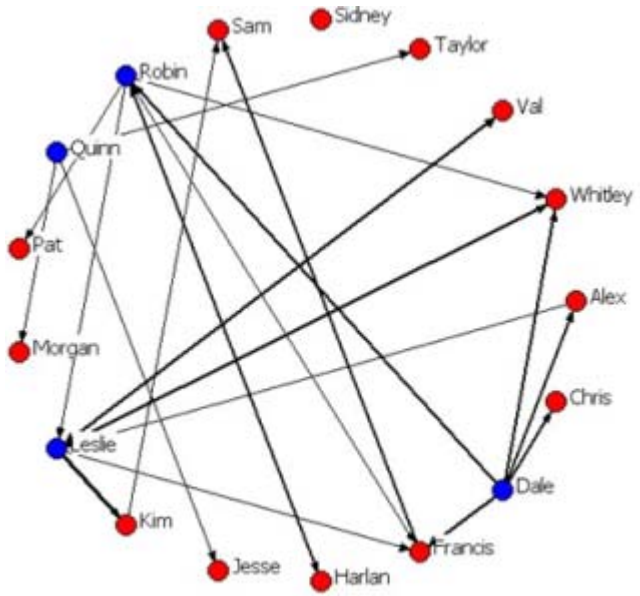
Network Structural Cohesion



Blocks and Cutpoints



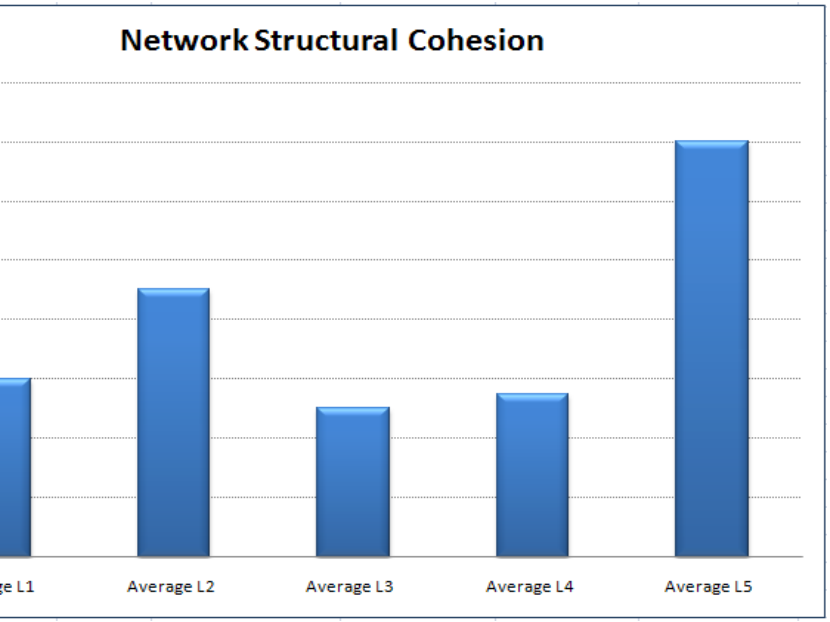
L3 01 Blocks and Cutpoints

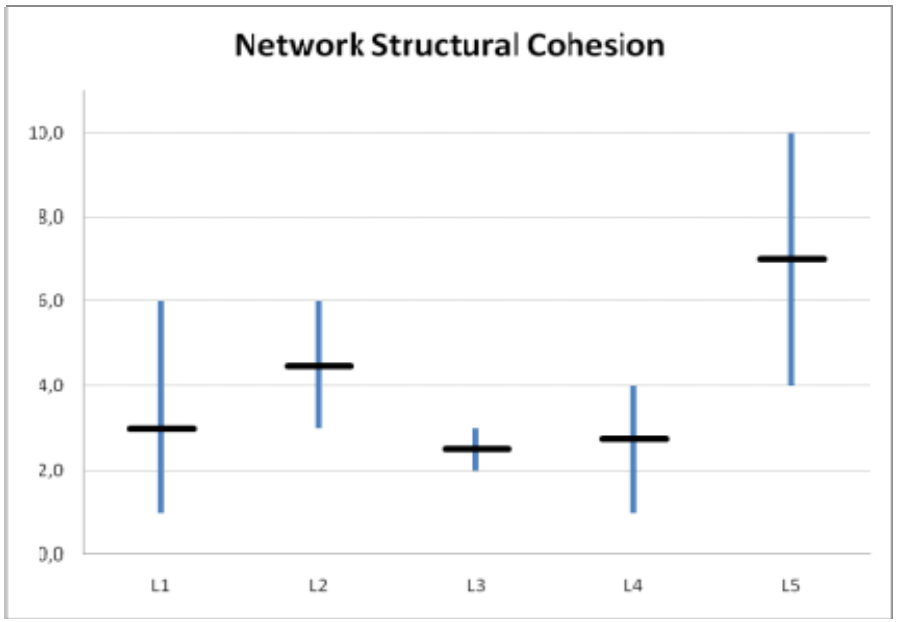


L5 02 Blocks and Cutpoints

SNA Findings in the N2C2M2 ELICIT Experiments

Network Structural Cohesion





A Variable	*Expected SNA Variable Behaviour From Less Mature To More Mature C2 Approaches*
uctural Cohesion	From LOW (small network cohesion) to VERY LOW (minimum network cohesion) and to HIGH (high network cohesion)

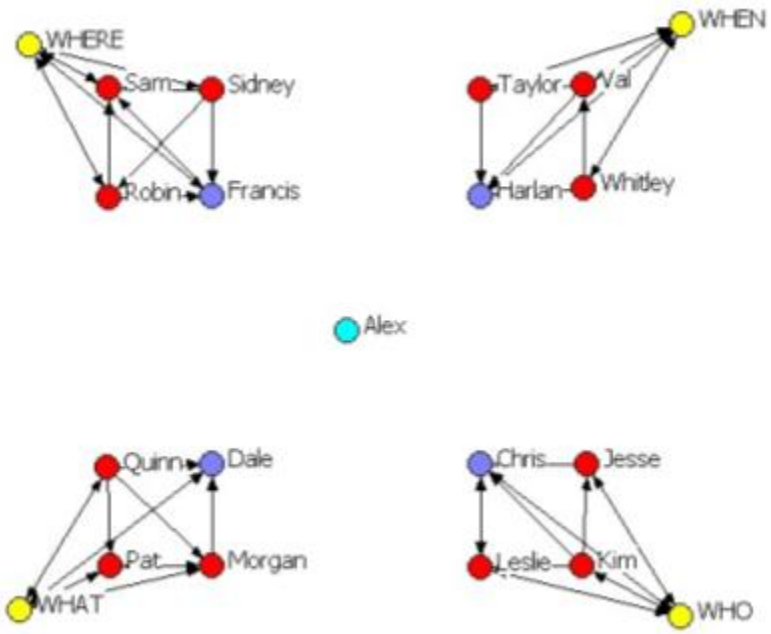
SNA Findings in the N2C2M2 ELICIT Experiments

Node Centrality			Node Embeddedness			Network Activity	Network Average Path Length	Network Inclusiveness	Network Clustering Coefficient	Network Connectedness	Network Structural Cohesion
etweenness	Degree	Closeness	Link Density	Link Strength	Link Flow						
0,196	2,529	2,627	0,196	2,529	2,627	291	0,138	0,058	10,00	14%	3
16,157	2,667	6,903	0,536	6,941	22,725	490	0,950	0,000	8,00	16%	7
16,182	2,824	7,010	0,614	5,863	17,373	400	0,616	0,000	9,00	17%	5
2,852	2,098	8,098	0,154	1,627	6,314	704	0,471	0,157	9,67	19%	3
5,059	2,745	6,363	0,208	1,392	7,176	981	0,561	0,147	8,67	16%	7

Evolving From Less Mature to More Mature C2 Approaches

L1 Conflicted C2 Approach

Low **node centrality**
Low **node embeddedness**
Constrained/Low **network activity**
Geodesic **path lengths**
Lowest **network diameter**
Low **inclusiveness**
High **clustering coefficient**
Reduced **connectedness**
Poor **network structural cohesion**



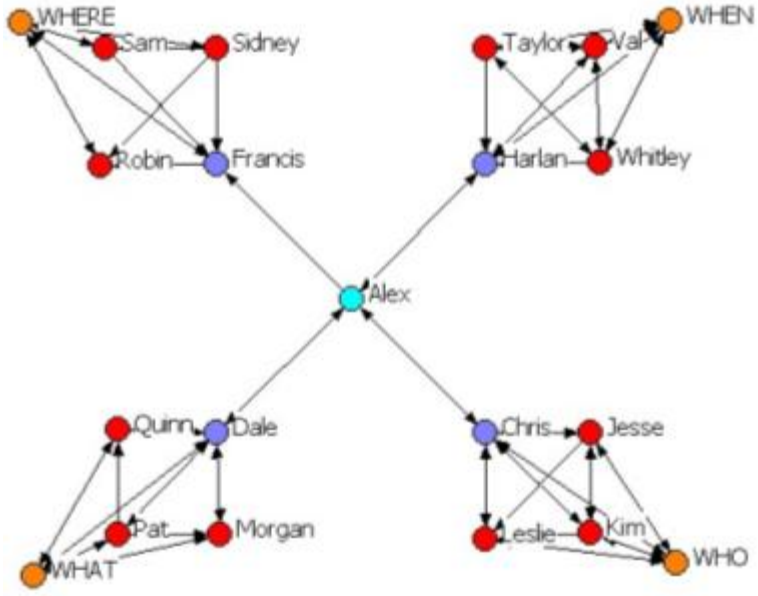
L1 03 Sociogram with websites

In 2 out of 3 runs, **one team solves its own problem space**
Very Low organisational success (mean value = 31%)

Evolving From Less Mature to More Mature C2 Approaches

L2 Deconflicted C2 Approach

- High **node centrality**
- Highest **node embeddedness**
- Enlarged/Medium **network activity**
- Largest **path lengths**
- Widest **network diameter**
- No **inclusiveness**
- Reduced **clustering coefficient**
- High **connectedness**
- High **network structural cohesion**



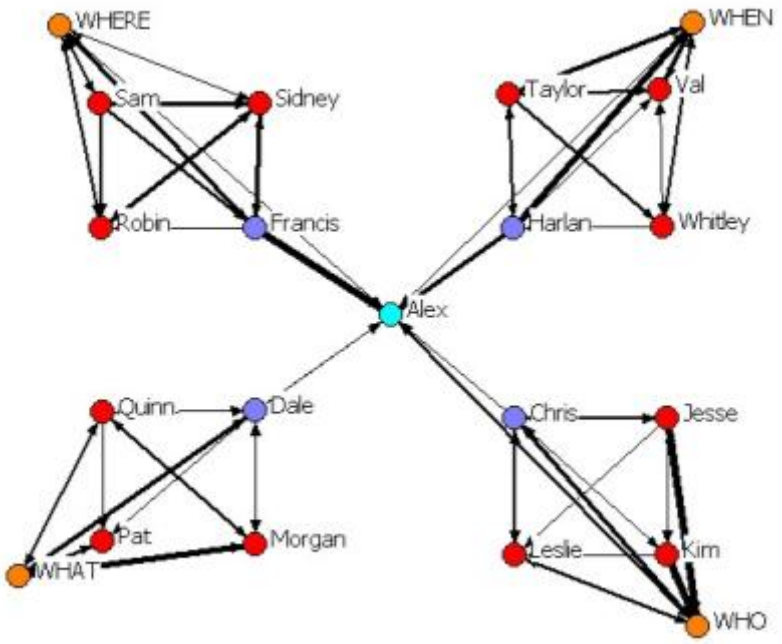
L2 01 Sociogram with websites

- In 3 out of 4 runs, **two teams solve their own problem spaces**
- **Low** organisational success (mean value = 44%)

Evolving From Less Mature to More Mature C2 Approaches

L3 Coordinated C2 Approach

Highest **node centrality**
High **node embeddedness**
Medium **network activity**
Large **path lengths**
Wide **network diameter**
No **inclusiveness**
Highest **clustering coefficient**
High **connectedness**
Medium **network structural cohesion**



L3 04 Sociogram with websites

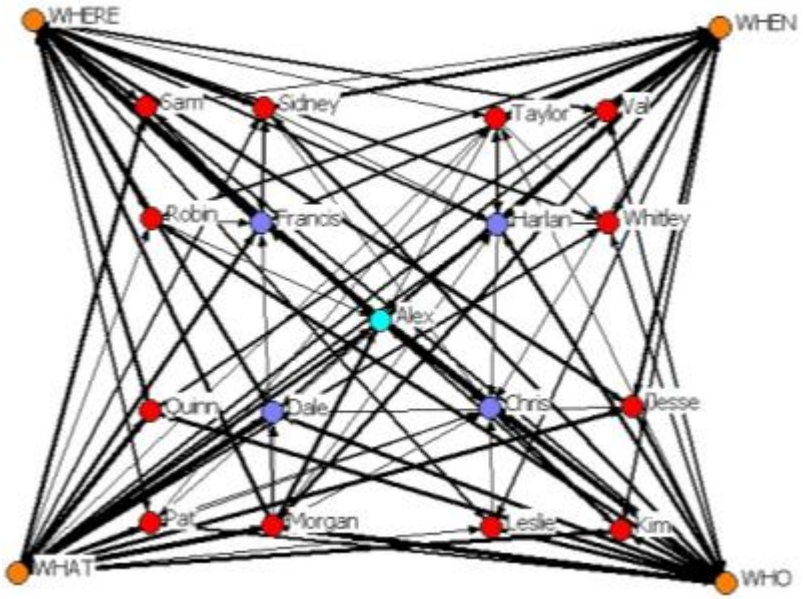
In 3 out of 4 runs, the Coordinator solved at most one problem space

Very Low organisational success (mean value = 34%)

Evolving From Less Mature to More Mature C2 Approaches

L4 Collaborative C2 Approach

Low **node centrality**
Low **node embeddedness**
High **network activity**
Smallest **path lengths**
Small **network diameter**
Highest **inclusiveness**
Lowest **clustering coefficient**
Highest **connectedness**
Low **network structural cohesion**



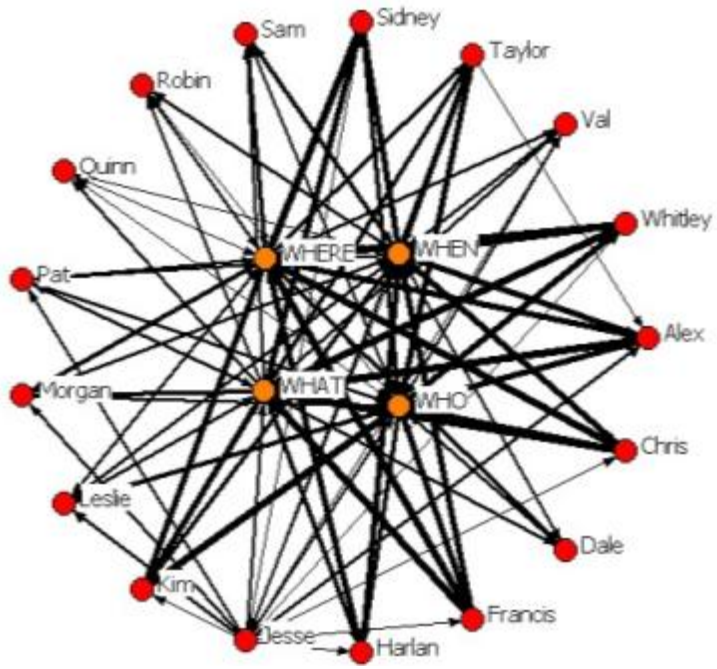
L4 01 Sociogram with websites

In 3 out of 4 runs, **three teams solve their own problem spaces or the Facilitator solves three problem spaces**
High organisational success (mean value = 80%)

Evolving From Less Mature to More Mature C2 Approaches

L5 Edge C2 Approach

Medium **node centrality**
Medium **node embeddedness**
Highest **network activity**
Small **path lengths**
Large **network diameter**
Medium **inclusiveness**
Low **clustering coefficient**
High **connectedness**
Highest **network structural cohesion**



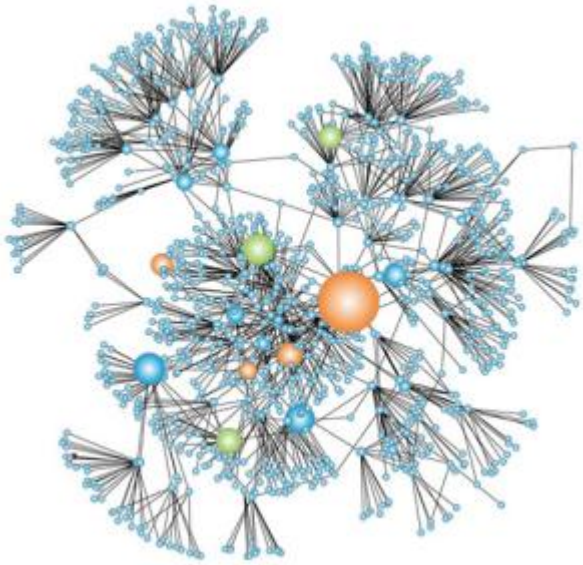
L5 03 Sociogram with websites

IDs plurality in 3 out of 4 problem spaces are correct
Moderate organisational success (mean value = 61%)

Knowing the Network, Knitting the Network

SNA is successful in displaying ganisational networking.

The power of **knowing the network** ables the opportunity to actively anage it or **knit it**.



SNA is a tool to build creative organisations, based upon **teraction dynamics** and **collaboration facilities,** so as to liver **enhanced performance** and achieve **success.**

..:: Thank You for Your Attention ::..

Questions?